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Flood Management Enhancement Using Remotely Sensed Data

Flood Management Prototype System Design Concept

Prepared by
Gregory J. Romanowski
Gregory A. Hodges

SENTAR, Inc.
4910 Corporate Drive, Suite C
Huntsville, AL 35805
(205) 430-0860

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Goddard Space Flight Center, Code 912
Greenbelt, Road
Greenbelt, MD 20771

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FOR A SYSTEM TO INTEGRATE REMOTE SENSING DATA INTO EMERGENCY MANAGEMENT OPERATIONS

INTRODUCTION

Background

This document presents the design concept for a prototype system that integrates remote sensing and spatial feature data into a emergency management tool to support disaster emergency management activities. The prototype system is to be developed for use by the emergency operations staff at the Emergency Operations Center (EOC) of the Alabama Emergency Management Agency (EMA). The concept developer was SENTAR, Incorporated, of Huntsville, Alabama, assisted by the NASA/Marshall Space Flight Center Global Hydrology and Climate Center (GHCC), the Alabama EMA, and the U.S. Army Space and Strategic Defense Command (USASSDC).

There is a need in the emergency management community to have, and have access to, current information on the climate, weather, and manmade infrastructure (i.e., roads, political boundaries, hospitals, etc.) as source data for use in the planning, warning, and assessment of disasters. To date, such information has been compiled by multiple organizations and stored in multiple formats and media, making it difficult to bring the data together to support emergency management operations. In addition, there is a need for more timely and detailed assessments of the location, area, and extent of the damage from a disaster to aid in response and recovery activities, particularly in image form.

The computer hardware and software required to manipulate and display the various geospatial data sets for the above mentioned data categories has only recently been available on standard microcomputers versus powerful workstations. The current microcomputers now have both the processing power and memory capacities to effectively manage the large volumes of data necessary to work with geospatial data. When coupled with the current Geographical Information System (GIS) software for manipulating and displaying geospatial data, the technology is now ready to support the needs of users such as state emergency operations staffs.

A third technology area that now is also capable of effectively supporting the emergency operations staff is the Internet. There is now a wealth of near real-time information available via the Internet that is of value for emergency management, and the associated tools to extract the information. An array of government organizations and commercial companies are offering numerous weather and climate data products on-line. Through these products, the technical expertise of those organizations for interpreting the source data is made available to the emergency operations staff. The Internet also provides a gateway to archival data sources that previously were either not available or at best time-consuming to acquire.

These tools and technologies, when integrated, can provide tremendous power to emergency management staffs in bringing together all the data sets they use to support their disaster related activities. The concept presented here addresses the implementation of a prototype system that will address the specific data and operations that the emergency management staff deal with for floods.

Prototype System Objectives

The objectives of the prototype system are to demonstrate the added value of remote sensing data for emergency management operations during floods and the ability of the Internet to provide the primary communications medium for the system. The key to achieving these objectives will be the development of the Emergency Management Tool that will provide an integrated interface

for the emergency operations staff to acquire and manipulate source data and data products to generate and distribute new data products to support their mission. The prototype system will also establish a systems infrastructure that is easily expandable to include additional flood-related data and models or to other disasters with their associated remote sensing data requirements and distributed data sources.

Document Overview

The intent of this document is to define the design concept of the prototype system. It is the basis for the actual software design for the software components to be developed. As such, it defines the software and hardware environment design constraints and drivers, the basic operational functions and products of the prototype system, the software components to be developed, and the data interfaces for the prototype system. This material is presented in four major sections in addition to this introductory section. The four sections are: Design Overview, Operational Overview, Design Description, and Data Interfaces, respectively.

Under the Design Overview section, there will be four subsections to address: the system concept, design drivers, software reuse strategy, and system-level interfaces and data flow.

The Operational Overview subsection describes how the prototype system operates for three modes of emergency management. The modes addressed are: prediction, warning, and assessment. For each mode, the system operation is described in terms of the products that are generated to support that phase, how these products are generated by the EOC users, and how the products are provided to the external users.

The Design Description subsection describes the major functional requirement of the software components to be developed for the prototype system. The functional requirements focuses on the processing performed, internal and external interfaces, data flow, inputs and outputs, and user interface.

The final section, Data Interfaces, describes the external and major internal interfaces for the system prototype source data. Each subsection describes one of the source data types in terms of the source, the transfer media, its use with in the system, and its path through the system elements. For some data types, there will be more than one path the data may take through the system. These cases are identified and the factors are identified to select the specific path through the system.

Examples of the various graphics products to be generated by the prototype system or downloaded from the Internet are included in the document. These figures are in black and white in the document, though they will be in color in the prototype system. Many of these graphics make extensive use of color to convey information that is lost in the black and white versions.

DESIGN OVERVIEW

System Concept

Figure 1 presents the overall design concept for the prototype system. The major system components are a Data Processing Center (in Huntsville, AL), the Alabama EMA EOC (in Clanton, AL), external data sources, and remote or county-level users. The Data Processing Center accesses spatial feature data and remote sensing data from various sources and processes the data for storage and use at the Alabama EMA EOC. At the EOC, the processed data will be stored for use by emergency operations staff. In addition, other remote sensing and emergency management data/information will be accessed and stored at the EOC directly from external sources. These data will then be used by the emergency operations staff through an Emergency Management Tool to produce graphical products for use by the field county EMA users. The Emergency Management Tool is the software program that creates a common user interface for accessing the suite of software applications for utilizing the data. The principal software

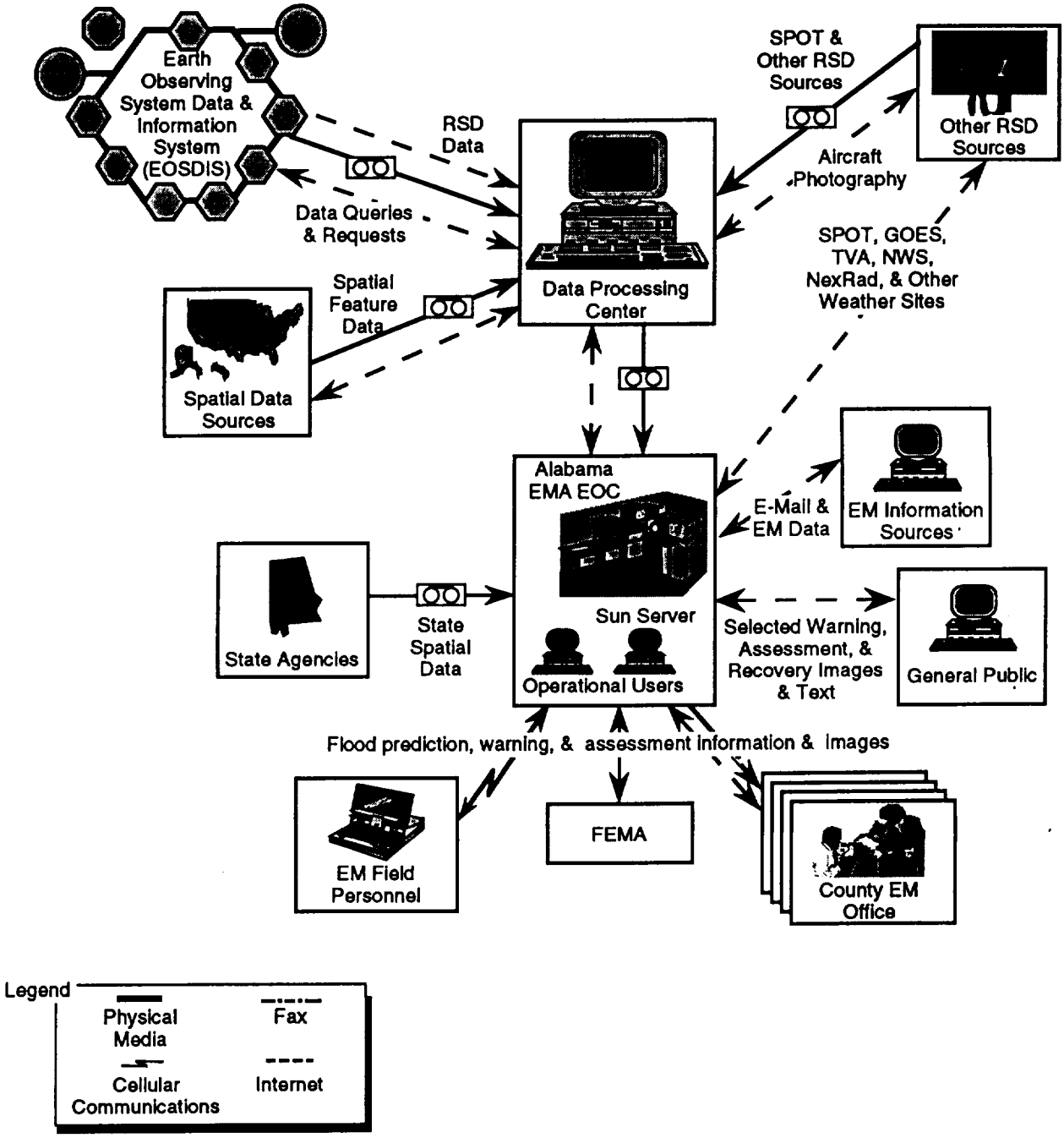

Figure 1. Design Concept for the Prototype System.

applications accessible from the software suite will be a GIS viewer for displaying, combining, and analyzing the data stored in georeferenced data coverages (or data layers) and a World Wide Web (WWW) browser for viewing GIF and JPEG imagery. It is with in the GIS viewer where different data sets will be combined to produce the data products to support emergency operations both internal to the EOC and for external users -- primarily field and county EMA users. Some of these data products will also be incorporated into a WWW Home Page, which will provide for public access to selected emergency planning, disaster assessment, and recovery information via the Internet.

The system design concept is built around five separate and distinct sets of basic activities:

- Collect source data from various organizations
- Process selected source data into GIS data layers
- Store GIS data layers and other source data for use by software tools
- Combine data to produce emergency management products
- Transport data products to emergency operations staff and the public.

Collect Source Data. Nearly all the spatial data needed by the emergency operations staff are maintained by other organizations. Thus, the system design is built on the concept of collecting versus generating source spatial data. The necessary data were defined by the Alabama EMA emergency operations staff. TABLE 1 identifies these data categories (or data layers) and groups them under 13 thematic areas. The data layers and the associated data attributes are listed in TABLE 2. The source data for these data layers and attributes will be acquired from a variety of data sources to include governmental, commercial, and educational organizations. The remote sensing data included in the prototype system were identified by SENTAR and GHCC staff. These source data consist of the actual sensor data and derived products from the original sensor data. Both types of data will be acquired using a combination of non-automated (printed pages) and electronic (tapes, disks, and the Internet) transport mechanisms. They will enter the system through the Data Processing Center or the Alabama EMA EOC, depending on the type of data and type of data processing required. The system will be designed to provide flexibility in the importing of source data so it can readily accommodate the addition of alternative data sources as they become available. For the prototype system, the types of data that will be collected include:

- High-resolution satellite imagery (i.e., Landsat and SPOT)
- Man-made infrastructure spatial data (i.e., roads, airports, political boundaries, etc.)
- Land feature spatial data (i.e., hydrology, terrain elevations)
- Satellite and ground weather imagery (i.e., Geostationary Operational Environmental Satellite and NEXRAD)
- Aircraft photography
- National Weather Service (NWS) weather forecasts and flood warnings
- NWS aerial extent of snow cover and surface air temperatures
- Tennessee Valley Authority (TVA) lake levels and stream flows
- Commercial flood warnings (i.e., the FloodCast predictions)
- Satellite microwave radar imagery.

TABLE 1. Thematic Groups of Data Layers

THEME	DATA LAYERS		
Hydrology	FEMA Flood Maps Hydrography Lake Levels Streamflows	Wetlands (D) USACE Flood plains	Snow & Rain Accumul. (D) Coastal Hydrology
Utilities	EAS Radio Coverage Doppler Radar (D) Burn Sites Sewer Systems	Fresh Water Systems Fuel Facilities Water/Sewer Treatment Plants	Transmission Lines (D) Electric Power grid (D) Solid Waste Sites
Geology	Surface Geology (D)	Elevation Contours	
Boundaries	Military Installations Built-Up Areas County Bound. International Bound.	Local Government Bound. State Administrative Bound. Federal Administrative Bound. Census Geography	Facility Bound. Military Leased Lands Restricted Areas
Socioeconomic	Demographics (population) Economic (income) (D)	Demographics (over 55)	
Geodetic	USGS Control Points		
Hazards/ Environmental	Hazardous/Toxic/ Radioactive Wastes	Medical Wastes Hazardous Materials	
Man-Made Features and Structures	Nuclear Plants Fire Departments EOCs Roads & Streets Maritime Ports	Bridges Airports Hospitals Police Departments Designated Shelters	Pipelines Railroads Power Plants Gov't Man-Made Structures
Photogrammetric	Photos and Imagery		
Cultural Resources	Historical Standing Sites and Graveyards		
Land Use/Land Cover	Land Cover/Land Use		
Emergency Planning Enhancements	Evacuation Routes	Disabled, Nursing Homes	
Remote Sensing	Land/Water Classification TVA Lake & Streamflow Data	Flood Warnings Surface Temperature Snow Cover	

TABLE 2. Prototype System GIS Data Layers

Priority [see note]	Data Layer	Data Source		Attributes	
		Primary	Secondary	No.	Names
1. Hydrology					
1	Hydrography	TIGER	USGS DLG	2	Feature Name, Census Feature Class Code (CFCC)
1A	FEMA Flood Data	FEMA	Insurance Institute	6	Area, Map Parcel, Flood Way, Hazard Zone, Flood Elevations, FIPS Code
1A	USACE Flood Plain	USACE		4	Area, Hazard Zone, Flood Elevations, FIPS
2	Coastal Hydrology	SeaLAB of Dolphin Island			TBD based on source data
Deferred	Wet Lands	US Fish & Wildlife	USGS		
Deferred	Snow and Rain Accumulation.	DLG			
2. Utilities					
1	Fuel Facilities	ADEM	TIGER, Counties & Cities	6	Type (well, tank farm, storage), Capacity, Capacity Units, Contents, State (solid, liquid, gas), By-products
1	EAS Radio Coverage	State	NOAA	4	Transmitter Name, Address, POC, Telephone #
1A	Fresh Water Systems	ADEM	Counties & Cities	3	Type (other, water lines, aqueduct), Diameter, Facility Name
1A	Sewer Systems	ADEM	Counties & Cities	2	Diameter, Facility Name
1A	Water/Sewer Treatment Plants	ADEM	Counties & Cities	5	Name, Address, Type, Diameter, Owner
2	Solid Waste Disposal Sites	ADEM	Counties & Cities	4	Type (public, private) Waste Type (inert, tires, construc-tion debris, concrete & block), Facility Name, Address
2	Burn Sites	ADEM	Counties & Cities	6	Type (public, private), Waste Type (medical, POL, other), Facility Name, Address
Deferred	Transmission Lines	FEMA	DLG		
Deferred	Electrical Power Grids				
Deferred	Doppler Radar				
3. Geology					
1	Elevation Contours	USGS DEM	DMA DTED	2	Type, Elevation
Deferred	Surface Geology	State, USGS Maps			

4. Boundaries					
1	County Boundaries	TIGER	USGS DLG	2	State, County (FIPS)
1	State Admin. Boundaries	TIGER		3	State, Type, CFCC
1	International Boundaries	TIGER	USGS DLG	2	Type, ID Code
1	Local Boundaries (cities, etc.)	TIGER		3	Local Name, County, State
1	Federal Boundaries (parks, etc.)	AL Conserva-tion Department			TBD based on source data
1A	Military Installation	Military Installations	USASSDC, USGS, Maps	2	Type, ID Code
2	Built-Up Areas	TIGER		1	Name
2	Census Geography	TIGER			TBD
3	Restricted Areas	State, Military Installations	Counties & Cities	4	Area Name, Managing Agency, Type
3A	Facility Boundaries	Gov/Military Installations		2	Name, Type
3A	Military Leased Land	Military Installation	None	2	Type, ID Code
5. Socioeconomic					
2	Demographics (population)	TIGER	USGS DLG	5	State & County Names, Block & Group, Number, Housing Units
2	Demographics (over 55)	TIGER	USGS DLG	5	State & County Names, Block & Group, Housing Units
Deferred	Economics (income)				Income and House Values
6. Geodetic					
2	USGS Control Points	USGS		1	ID Number
7. Hazards/Environmental					
1A	Hazardous/Toxic/Radioactive Waste	ADEM	Counties, Cities & Military Installations	3	EPA Number, Facility Name, Address
1A	Hazardous Materials (also private incinerators, medical waste)	ADEM	Counties, Cities & Military Installations	3	EPA Number, Facility Name, Address
2	Medical Waste	ADEM			
8. Man-Made Features and Structures					
1	Roads and Streets	TIGER	USGS DLG	5	CFCC, Feature Name, Feature Type, Alt. Feature Names
1	Airports	DMA DAFAF	USGS DLG	2	Feature Name, No-Fly Zone
1	Railroads	TIGER	USGS DLG	3	CFCC, Feature Name, Feature Type
1	Nuclear Plants	State	EIS, FEMA	5	Site Name, Category, Type (technology), Buffer Dist., Operations Phone #, Street Address
1	EOCs	AEMA		3	EOC Name, Address, Phone #

1	Hospitals	AL Dept. of Public Health	FEMA, TIGER	4	Name, Operations Phone #, Address, Number of Beds
1	Designated Shelters	AEMA		4	Shelter Name, Hazard Type, Address, Phone #
1A	Bridges	AL DOT		3	Load Capacity, Overhead Clearance, Elevation
2	Pipelines	County, City, State, Military Installations	Corps of Engineers	4	Owner, Type, Diameter, Contents
2	Power Plants	State, TVA, APC, Co-Ops, Military Installations	Counties & Cities	5	Facility Name, Category, Owner, (classification), Address, Phone #
2	Government Man-Made Structures	State, Military Installations	Counties & Cities	5	Description, Owner, Type (city, county eng office, county courthouse, Gov level, etc.) Address, Phone #
3	Maritime Ports	SWSA		1	Name
3	Police Departments	State, Counties & Cities		3	Dept. Name, Operations Phone #, Address
3	Fire Departments	AL Fire College	Counties & Cities	4	Type (public, volunteer, private, commercial), Name, Operations Phone #, Capabilities (bomb, HAZMAT)
9. Photogrammetric					
1	Photos and Imagery	EDC, Aircraft Photos	SPOT	6	Source, Image type (picture, satellite, movie, TV), Registration Lat./Long., Resolution, Tile #, Image Date
10. Cultural Resources					
3	Historic Standing Sites and Graveyards	Historical Commission	National Historic Registry	4	Facility Name, Owner, Phone #, Type (including maritime sites, prehistoric archeological sites, Native American sites)
11. Land Use/Land Cover					
3	Land Use/Land Cover	USGS DLG	Counties & Cities	1	Type
12. Emergency Planning Enhancements					
1	Evacuation Routes	AEMA	County EMAs	1	Route Type
1	Disables, Nursing Homes	AL Commission for the Aging		3	Facility Name, Owner, Phone #, Number of Beds, Address
13. Remote Sensing					
1	Land/Water Classification	EDC, Aircraft Photos	SPOT	5	Class Type, Location, Source, Projection, Date

1	TVA Lake & Stream Flow Data	TVA		5	Sensor Type, Name, Location, Sensor Value, Date, Time
1	Flood Warnings	NWS	Floodwatch	4	Source, Type, Start Time/ Date, End Time/Date
2	Surface Temperature	NOHRSC			Temperature
2	Snow Cover	NOHRSC			Cover Type

Note: Priority definitions

1	Top priority, must be included in initial version
2	Desirable for initial version if data availability and resources permit
3	Lowest priority, deferred to a follow-on effort
A	If available
Deferred	Lesser priority data layer; deferred to another effort
Dropped	Determined not to be needed at the installation EOC

There are other sources that are just becoming available that would be beneficial to this system but are not currently part of the formal design concept. These include the RADARSAT system for satellite radar imagery, the Hydrologic Research Center's flash flood prediction system (provides a more refined areas definition of potential flash flood areas than the current NWS predictions) [Sperfslage, 1995], and the National Oceanic and Atmospheric Administration's (NOAA's) Water Resources Forecasting System (WARFS) program [Ingram, 1996].

Process Source Data. The processing activities consist primarily of converting textual and imagery files into GIS data layers and georeferenced raster files that will constitute the GIS database at the Alabama EMA EOC. There will be an initial GIS database development effort that will involve the processing of source data that are relatively time invariant (e.g., roads, political boundaries, and archival imagery). The data processing for these data will be done prior to the operation of the prototype, with periodic maintenance when the source data are updated. There will also be an on-going GIS database development effort for those data sources that change frequently and are disaster dependent. This would include text files of TVA lake and stream flows and the NWS flood warnings, and image files of satellite and aircraft photography.

The man-made infrastructure spatial data and land feature data will be entered directly into the GIS software. Once ported into the GIS software, the source data will be converted into one or more data layers with associated data attributes for each data layer. The source data that are U.S.-wide, and thus non-specific to Alabama (such as roads and political boundaries), will be processed at the Data Processing Center, while the source data that are specific to Alabama (such as power plants, hospitals) will be processed at the Alabama EMA EOC. Specifically, the first group of data layers will consist of the data layers from the thematic groups: hydrology, geology, boundaries, socioeconomic, geodetic, land use/land cover, and part of man-made features and structures. The second group will consist of the data layers from the thematic groups: utilities, hazard/environmental, cultural resources, emergency planning enhancements, and part of made-made features and structures. (See TABLE 1 for list of thematic groups and corresponding data layers.) This division naturally derives from the fact that the source data from the data layers in the second group originates with departments and agencies within Alabama. Conversely, the source data for the first group generally provides data for the entire U.S. rather than just Alabama. In addition, the source data for the second group will generally be updated at a more frequent rate and thus will require more frequent maintenance of the GIS database. In either case, macros will be developed with the ARC Macro Language (AML) to process source data into ARC/INFO formatted data coverage files. The data layers from the Data Processing Center

will be transported to the EOC upon completion where they will be combined with the data layers processed at the EOC to form the initial GIS database.

The GIS database will also contain certain remote sensing data derived data layers and image overlays. The former will include the NWS county flood warnings, the TVA lake and stream flows, and land/water classifications from satellite imagery and aircraft photography. The first two of these are text file source data and will be brought directly to the EOC for processing into GIS data layers. The second two are generated from imagery and photography data and will be processed at the Data Processing Center. The use of the Data Processing Center is required due to the human remote sensing expertise required, more than the availability of the imaging software tool. The imagery overlays are satellite imagery or aircraft photography that has been created into a raster file that is georeferenced and formatted for importing into the GIS software. These raster images will be used as backdrops on which the other GIS data will be overlaid and will be used to perform temporal analyses to show areas currently under water versus the normal water boundaries.

The major steps involved in the image and photography processing will consist of:

- Scanning to create digital images of hardcopy photographs
- Reformatting from source formats to image software format
- Image enhancement to modify the pixel values for improved feature definition
- Georeferencing to assign geographical coordinates to the image pixels
- Mosaicing of multiple images into a composite image (images maybe from different sources, i.e., Landsat and aircraft photography).

From here the processing is divided into the two products to be exported to the EOC. For the backdrop images, single band or multi-band images of selected processed bands are created from the source data and then formatted for exporting to the GIS software. Figure 2 illustrates an example of a backdrop image that is a composite of a space shuttle photograph and a Landsat MultiSpectral Scanner (MSS) image. For the land/water classification data layer, the pixels of the image will be categorized as either water or land based on the value of the pixels from a two-band scattergram. Figure 3 shows a scattergram for a Landsat MSS image of the same area of Figure 2, and Figure 4 shows the resulting land/water classification for the image. The classified image will then be exported to the GIS software where the water areas will be defined as polygon data layer.

Store Processed Data. All the collected and processed GIS and remote sensing data are stored in databases on a SUN Microsystems file server connected on the Alabama EMA Local Area Network (LAN) for access by any of the emergency operations staff. The primarily database will be the GIS database which will store all the GIS data layers. In addition, there will be databases for the backdrop remote sensing images and photography processed by the Data Processing Center and for the weather and remote sensing data collected from the Internet at the EOC. These consist of GOES imagery, NWS flood warnings, FloodCast predictions, TVA lake and streamflow data, NEXRAD imagery, and weather forecasts.

The GIS data layers will be grouped by counties to facilitate access by the emergency operations staff. Typically disasters affect a region encompassing one to a few counties. Thus, organizing the data layers by counties provides for the ability to extract only the areas of interest rather than having to sort through each data layer for the counties of interest. There are times when viewing the entire state is of interest. In these cases however only a limited number of data layers are needed or viewable on the standard PC monitor. These data layers consist of state boundaries, county boundaries, major water systems, and selected man-made fractures and structures (e.g., major highways). Separate coverage files will be built for these state-wide coverages. Due to

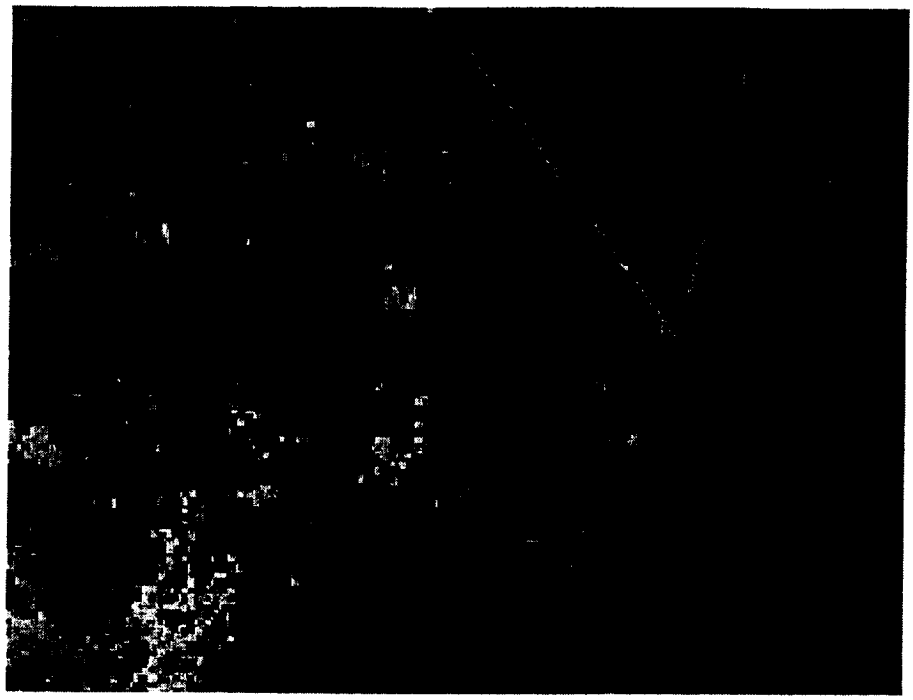

Figure 2. Backdrop Mosaic Image of a Space Shuttle Photograph and a Landsat MSS image (Shuttle on left side, Landsat MSS on right side)

the limited data in these files there will not be a significant storage impact to also include these files.

The prototype system GIS database will contain the selected state-level data coverages and the complete set of data layer coverages for two multi-county regions of Alabama. As a result, the size of the GIS database for the system prototype will not exceed the current 2 Gbytes of disk storage on the main file server, and the entire database can be kept on-line. Similarly, for the remote sensing images, these files will be kept on-line despite their large size (10s to 100s of Mbytes). As the system prototype is used more remote sensing data images will be included and it is anticipated that a large library of these images will quickly develop. Those images that are during a disaster, and therefore represent abnormal conditions, will be kept on-line until all disaster related work is completed. They will then be saved off-line on magnetic tape at the EOC.

Produce Emergency Management Products. The essence of the system prototype is to produce information products, primarily graphical, to enhance emergency management operations. An Emergency Management Tool will be developed for the emergency operations staff that incorporates existing software programs for the production of these products in three ways. First, there is the simple retrieving of relevant images from various Web home pages. These include such items as GOES satellite imagery, NEXRAD imagery, or NWS flood warnings. Here data are used as is. The improvement to the Emergency Management Staff is in the accessibility of important information in a timely manner. Where there is information processing with these data it will be performed visually by the staff versus the software.

The other two ways involve the production of images that integrate remote sensing data with the GIS data layers within the system. This integration can either be done at the Data Processing

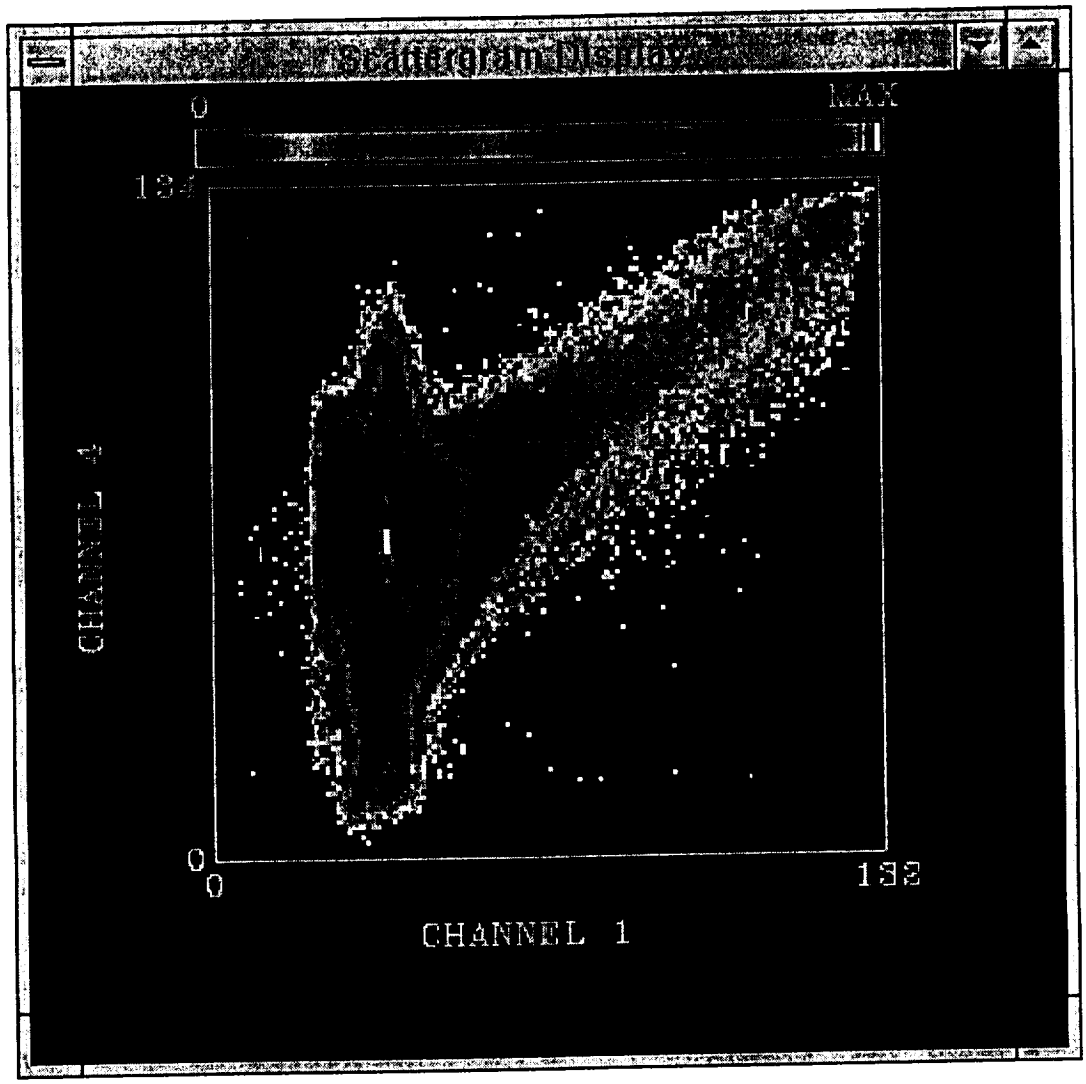

Figure 3. Landsat MSS Scattergram for Bands 1 and 4

Center or at the Alabama EMA EOC. For the former case, the remote sensing images form satellites or aircraft will be processed and then GIS feature data overlaid to create composite maps for transmittal to the Emergency Operations Staff at the EOC. These composite maps will be essentially view only products for the Emergency Operations Staff or for retransmittal to field users and county EMA offices, and therefore are referred to as static maps. (See Figure 5 for an example.) For the latter case, the processed remote sensing data from the Data Processing Center will be transmitted to the EOC in an ARC format for use with in ArcView with the GIS data layers stored in the GIS database. The specific displays of region, remote sensing data, and GIS data layers will be created by the Emergency Operations Staff using the tools within ArcView. The displays generated then can be used internal to the EOC or again created into a graphical map for transmittal to the field users and County EMA offices.

Figure 4. Land/Water Classification from the Landsat MSS Scattergram

The static maps produced by the Data Processing Center have the disadvantage that they do not permit the Emergency Operations Staff to utilize the ArcView tools. They will also not have all the data layers available at the EOC nor will they permit access to the data layer attributes. However, these maps have the advantage that they can be more rapidly produced and can be generated prior to the GIS database being in place at the EOC.

Communicate Data Products. The map displays retrieved from the Data Processing Center or via the WWW and those produced locally using ArcView will be used internally in the EOC by the emergency operations staff to perform their work. They will also export selected map products as GIF images to field users and county EMA offices. Exported images will be sent via FTP to Wide Area Network- (WAN) connected and Internet-accessible counties, or via fax to the remaining counties. Selected images and text will also be incorporated into a WWW home page to provide visual images and text-based recovery information to the general public via the Internet. For the system prototype, one of the system computers will be used to demonstrate this capability. However for an operational system, a separate computer must be used for the Web

Figure 5. Static Map Example

server so that the EOC file server does not become overwhelmed with information requests from the public and therefore useless for the emergency operations staff.

Design Drivers

The software design for the prototype system will be constrained by several design drivers. The following subsections identify these drivers and describe how they will constrain the software design.

Time. The system prototype development is constrained by the timeframe of the NASA Cooperative Agreement project. The original focus of this effort is the integration of Distributed Active Archive Center (DAAC) remote sensing data with a GIS. However, the work for the

design concept identified many sources of spatial data and remote sensing data that would enhance the prototype system. These data are from internal Alabama EMA models and other external data sources. In most cases, the key to utilizing these data is in resolving the interface issues necessary to import the data into the GIS software. Although the time constraints do not permit all of these data interface issues to be addressed, the design concept does incorporate at least one selected data type in each category to demonstrate how the data would be acquired, incorporated into a data layer, and used in the system in an operational version of this system. This approach will establish the feasibility and methodology for incorporating the other data in the future.

Hardware. The system must operate on the existing or planned equipment at the EOC, in Clanton, AL. This system consists of an internal LAN with Sun Microsystems and DEC file servers. The emergency operations staff will use DEC and IBM PCs (486 and above processors) operating of the LAN. The LAN also has external connections to the Data Systems Management Division in Montgomery, Alabama, and a WAN to six Alabama counties as part of the Chemical Stockpile Emergency Planning Program (CSEPP). Figure 6 presents a schematic of the EOC LAN showing these elements plus other peripheral equipment, and Figure 7 presents the WAN configuration.

Aside from the counties on the WAN, communications with the county level of emergency management officials are achieved either via computer to computer connections using modems or via telephones and fax machines. Some counties are connected to the EOC via a wide area network. Although no county EMA office presently has Internet access, the design will plan for some county to have such connectivity since some counties may have Internet access by the time the prototype is developed.

Software. The system will make extensive use of existing software products (see the following subsection entitled: Reuse Strategy). The system design will consider the existing software at Alabama EMA or those software packages already planned to be acquired to support the required functionality of this system, where possible. Where these software packages will not meet the functional needs, other existing software products will be considered to include commercial software. The design will attempt to minimize the software to be developed and to maximize the use of existing software at the EOC.

Source GIS Data. The source data needed for the GIS data layers defined for the prototype system are not maintained by the Alabama EMA, and thus, they cannot control the data release authorization and scheduling. The specific data layers populated will be those for which access to the source data is obtained from the source organization prior to the end of the fifth milestone period.

GIS Data Area Coverage. The prototype system will be designed to include GIS data for the entire state for each data layer. However for the system prototype, complete GIS data layer coverage will be created for only two multi-county areas in the state centered around Redstone Arsenal and Mobile. At least three data layers will be populated for the entire state to demonstrate the capability of the system to permit the user to create projects of selected areas from the complete database. In addition, other cases where the GIS source data is readily available for the entire state, the complete data set will be included in the GIS database.

Timelines. The timelines for the system are set by the needs of the Alabama EMA EOC staff as defined by their mission. Prediction will be anytime prior to an emergency situation up to the time an official warning is made and the EOC goes on standby alert. The warning period will then go from that time until an actual emergency is declared. The assessment period will cover the time when the emergency is declared through the response and recovery period. In specific time units, the prediction phase will be several days prior to a warning, the warning phase will last on the order of hours up to a few days (e.g., for a hurricane), and the assessment phase will last for up to two weeks.

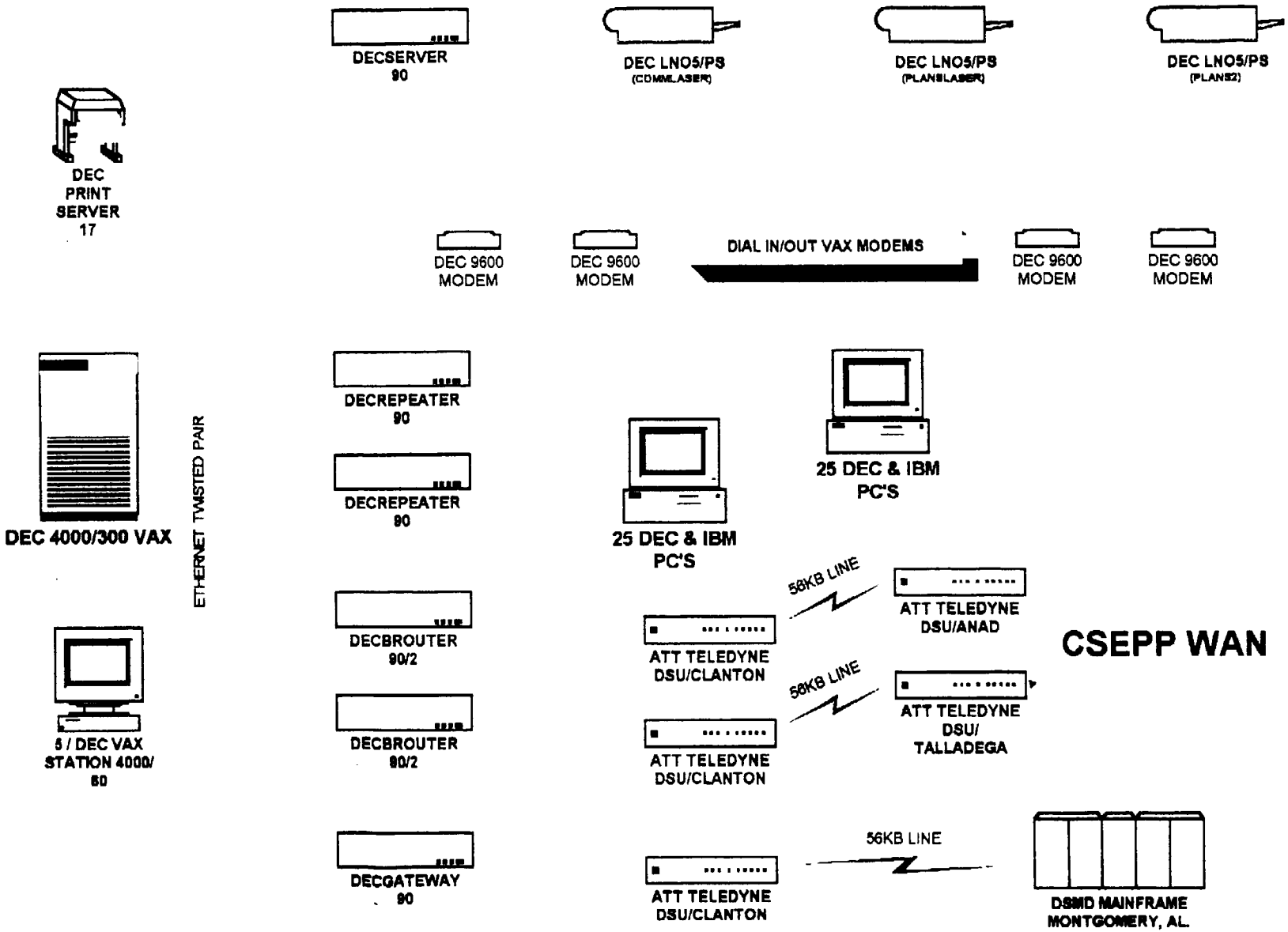

Figure 6. Alabama EMA EOC LAN

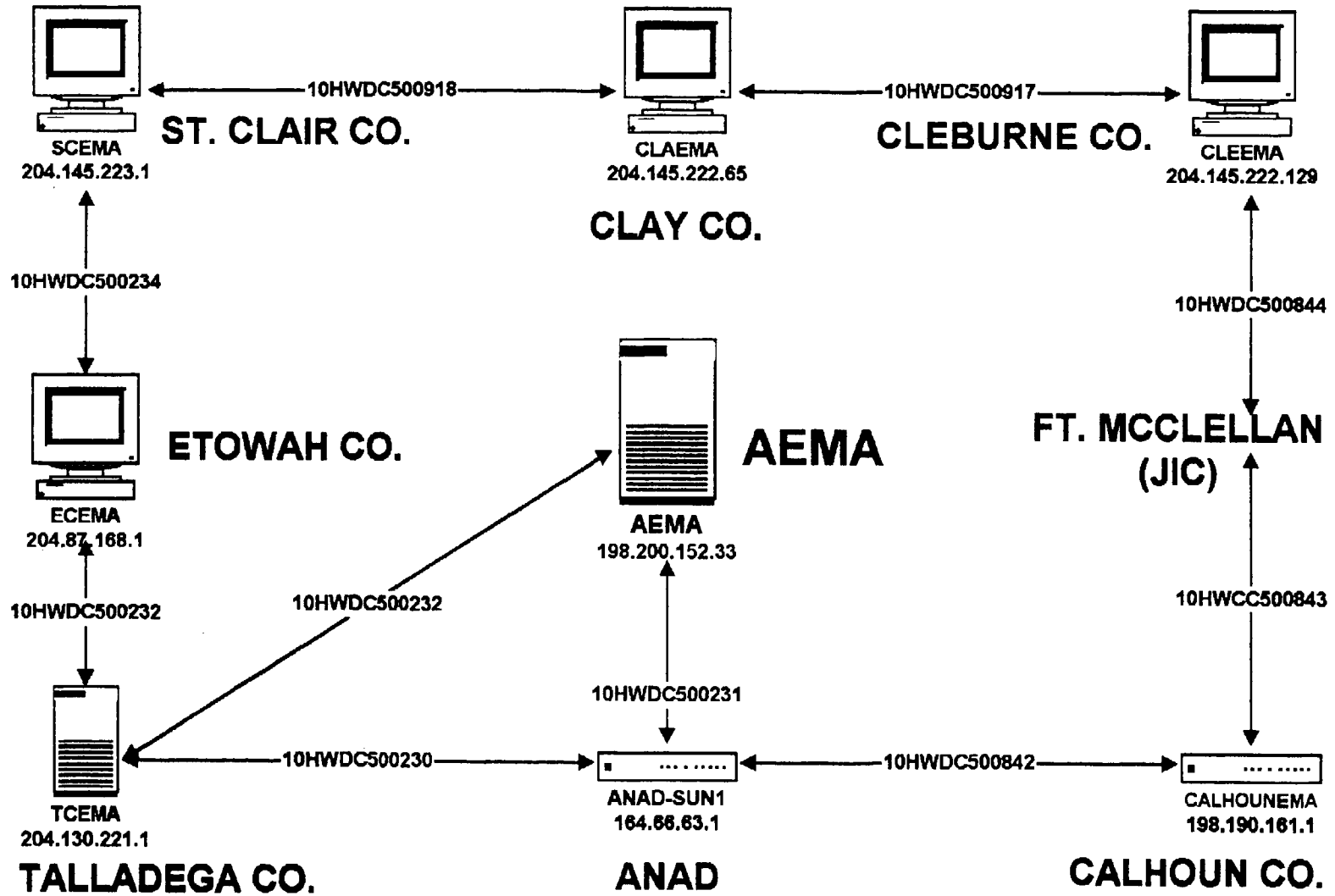

Figure 7. Alabama EMA CSEPP WAN Configuration

Data Communications. Data communications are a central part of the system due to the distributed nature of the system elements. The remote sensing data will be extracted from several data providers, brought to a processing center, then sent to Alabama EMA EOC for use by its staff, and ultimately passed down to county-level emergency management officials. Each of these elements involve computers at separate geographical locations. Since there is no existing network connectivity between all these locations, the Internet will be the data network in combination with the Alabama EMA LAN and WAN. When the data transfer requirements exceed the capacity of the Internet, alternative physical methods will be employed to transfer electronic data (e.g., via magnetic tapes).

Reuse Strategy

The reuse strategy for this system prototype is to integrate existing software applications through a common user interface to produce a tool for emergency managers. This strategy is predicated on the knowledge that there are existing software tools to perform the data processing and product generation necessary. The real need is therefore to provide the emergency operations staff with the ability to access the various data sets needed using these tools in a manner that is usable to them. The software tool that will be developed is essentially a common interface for the existing applications that are to be integrated into the prototype system. The other software to be developed will consist of various utilities needed to collect, process and store the data to support the system. All other functionality will be provided by a collection of commercial, government, and shareware software.

Where multiple choices exist, the existing or planned software of the Alabama EMA will be the first choice to provide the needed functionality. Next, the design shall consider government or shareware software to provide needed functionality. The use of additional commercial software will be limited to cases where specific functionality is needed, but not achievable by the other types.

System-Level Interfaces and Data Flow

The system-level interfaces and data flow are presented in terms of the three central components of the system prototype: the Data Processing Center, the Alabama EMA EOC server, and the emergency operations staff PCs (see Figure 1).

Data Processing Center. The Data Processing Center imports spatial data and remote sensing data for initial processing and subsequent product transmission to the EOC. Data processing is first performed to create the base GIS database of data layers and remote sensing backdrop images prior to the operational use of the system prototype. Later, the data processing will be primarily involved in the processing of remote sensing data acquired during operational use (See Figure 8).

Development of the base GIS database begins with the non-Alabama specific geographic data being processed into data layers. The source data will generally be in digital form and provided on tape or CD, or retrieved via FTP, as is the case for the Digital Line Graph and Digital Elevation Model (DEM) from the USGS. Any of the digital formats allow for essentially automated processing with manual quality control procedures. AMLs will be developed to perform the necessary processing of the source data files to create the necessary data layers and associated attributes. The complete data layers will be checked at the Data Processing Center using the ArcView GIS viewer software and then sent to the Alabama EMA EOC via magnetic tape.

Next, the initial set of remote sensing data will be identified and retrieved from the source locations through a combination of automated retrieval using FTP on the Internet and physical delivery via data tapes. These include Landsat satellite images from the Eros Data Center (EDC), SPOT satellite images from the SPOT Image Corp., satellite radar images (possibly from

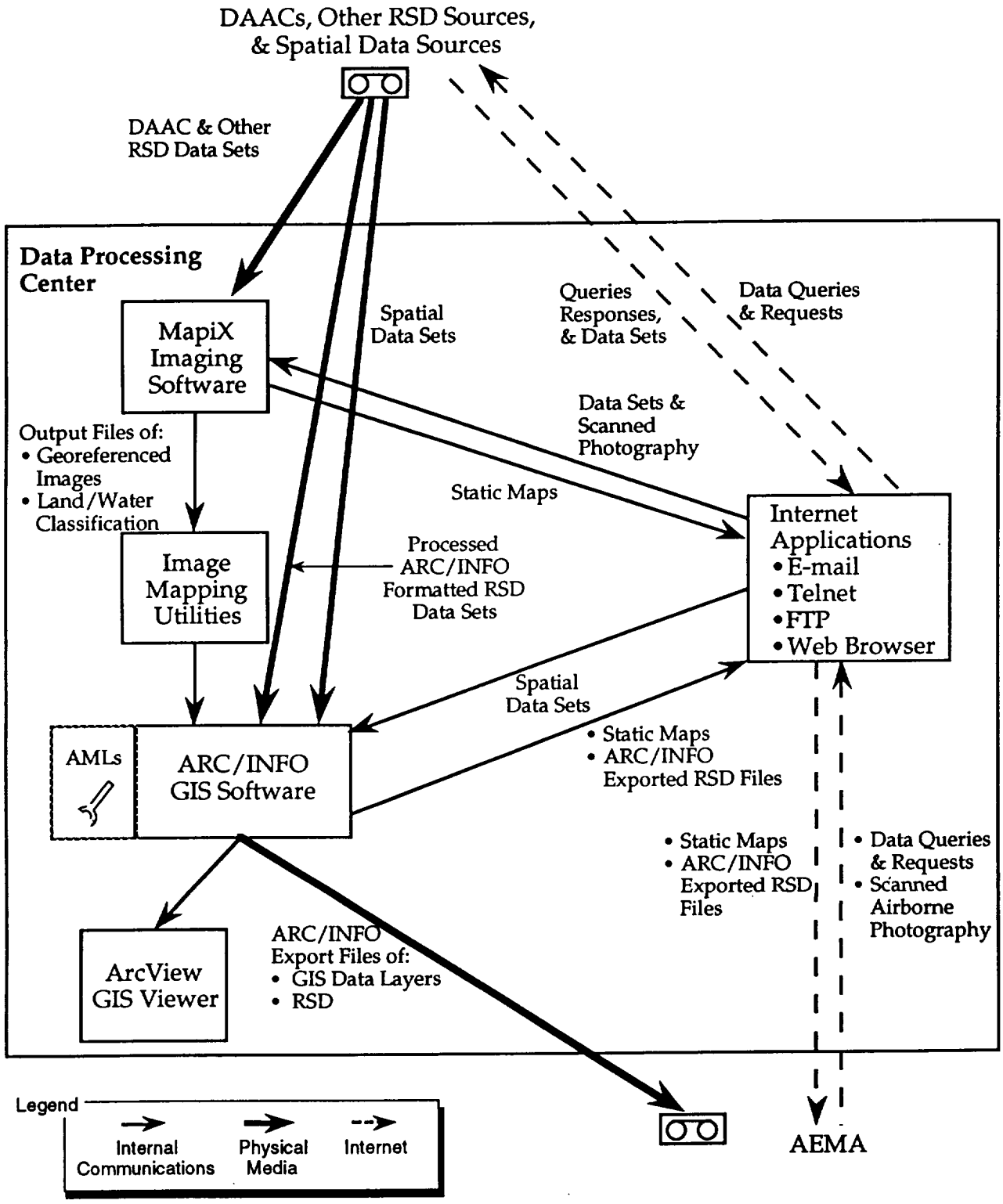

Figure 8. Data Processing Center Elements and Interfaces

the European Earth Resources Satellite, or in the future from RADARSAT), and aircraft photography from a variety of sources. The major methods for importing the aircraft images will be to scan the original photograph at the Data Processing Center or to scan the photograph at the Alabama EMA and FTP the digital file to the Data Processing Center. If available, a digital camera will also be used which will eliminate the scanning step.

For imagery data requiring reformatting and processing for input into ARC/INFO, the MapiX imaging software will be used to generate the image data products and then the Image Mapping Utilities will convert those products into a format for ARC/INFO to read. Some source remote sensing data can and will be acquired in ARC/INFO format from the source provider to demonstrate the ability to skip the imaging software and utilities at the Data Processing Center.

In any case, the remote sensing data will be enhanced, georeferenced, and then generated into a product image and classified for the land/water boundaries. Both data products will be exported in raster format for use by ARC/INFO and ArcView. A quality control check will be performed on the reformatted raster images prior to transport to the Alabama EMA EOC. Also, when appropriate, the GIS data layers processed at the Data Processing Center will be combined with the image products to product static maps for transmission to the EOC.

The completed data layers will be transferred to Alabama EMA via data tapes. This approach will be used due to the large size of the files and the one time nature of the transfer. Once the system is operational, updating of these data layers will be performed at Alabama EMA rather than the Data Processing Center. The image data will be transferred to the Alabama EMA via the Internet and the rest will be sent via data tapes. The initial transfer of data will involve large numbers of files, while future processed remote sensing data will generally be more limited and needed more expeditiously. In fact, once the initial GIS and imagery data is transferred, the Data Processing Center will be used primarily to process additional remote sensing data that require georeferencing, analysis, or reformatting.

Alabama EMA EOC Server. The Alabama EMA EOC Server is the central element of the system at the EOC. It imports the data layers, remote sensing image files, and static maps from the Data Processing Center and stores these files in the appropriate databases on the server disk. State spatial data is manually entered onto the server for ARC/INFO processing into additional data layer coverages and then stored in the GIS database. The server also imports remote sensing data from external sources for processing and storage or simply for storage. These databases are then accessed by the emergency operations staff through the applications in the Emergency Management Tool on their PCs. Map products from the Emergency Management Tool that are to be included in the WWW home page are uploaded from the PCs to the server. These external and internal interfaces are illustrated in Figure 9.

The interface with the Data Processing Center will be via tape for the GIS data layers and the initial remote sensing image products. After that, most of the data transferring between these two system elements will be via the Internet, except for very large image file transfer. The data transfer from the EOC to the Data Processing Center will consist of e-mail data queries and requests and FTP file transfers of scanned aircraft photography for processing. Data transfer in the reverse direction will consist of e-mail responses, static maps, and processed remote sensing data backdrop images and land/water classifications in ARC/INFO format.

The GIS data processing to be performed at the EOC involves spatial source data from Alabama state agencies that are generally not digitized, and thus requires an essentially manual process to convert the source data into an electronic format first. The AMLs needed to process the source data will be provided by the prototype developer, but the Alabama EMA staff will perform most of the manual data processing using the AMLs and ARC tools. This processing will include digitizing data from map sheets and data entry of hardcopy textual data. In the future, the

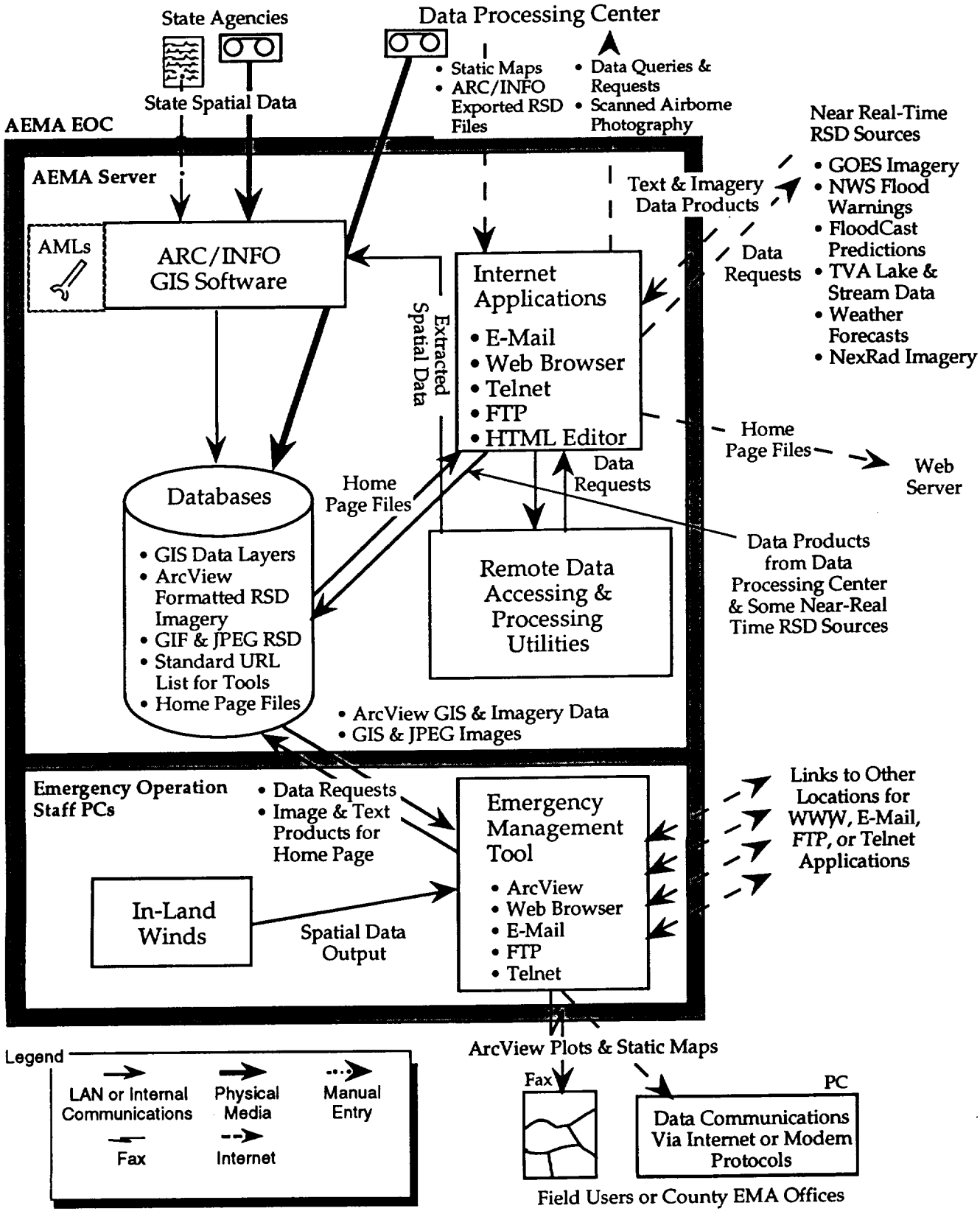

Figure 9. EOC System Components and Interfaces

agencies providing the source data will be automating their data, but none of these will be completed in time for the system prototype.

The GIS data layers from the Data Processing Center will be combined with the State geographic data and stored on the EOC server. Additional remote sensing data layers will be produced with the near real-time TVA lake and streamflow data and the NWS flood warning areas data to complete the GIS data layers of the system prototype. These additional remote sensing data layers will be produced by extracting the necessary data files at specified intervals from external, Internet-accessible Web or FTP servers, parsing the files for the desired information via a set of processing utilities, and creating the data layer with ARC/INFO and AMLs (note the data may in fact be stored in table files within ARC/INFO rather than actual coverage files).

Other remote sensing data will also be retrieved from external, Internet-accessible Web servers and stored as imagery for simple viewing. Specifically, this will include GOES, NEXRAD, and other weather images. System utilities will be developed to automatically download the images from on-line sources and then and store the imagery on the server for access by the emergency planners. This approach will reduce the bandwidth requirements by having only one copy of these large files being downloaded.

These databases are then made available to the emergency operations staff to support the applications in the Emergency Management Tool that they will use on their PCs, which communicate with the EOC central server via the internal LAN. The client application on the PCs will pull the appropriate data files form the server for use on the PCs. Selected map products will also be produced on these PCs for use by other staff and for incorporation into a WWW home page for public disaster and recovery information.

Emergency Operations Staff PCs. The emergency management staff will perform their work from their PCs. They will use the Emergency Management Tool, which is a graphical user interface that will be developed to integrate the COTS applications needed to access and manipulate the above mentioned databases on the EOC server and to produce map products with that data to aid in their disaster planning, warning, relief, and recovery operations. Figure 10 presents a pictorial view of the interfaces and data flows at Alabama EMA.

The primary application within the Emergency Management Tool will be the GIS viewing tool ArcView. The ArcView application will be customized to meet the specific needs of the Alabama EMA staff using the customizing tools within the application. For actual operational usage, the emergency operations staff will build a project file with ArcView. This would consist of retrieving from the server all the data layers and imagery data for the county or counties affected by the emergency situation. This subset of the database will provide a more manageable set of data to manipulate, and can be shared by all staff working the emergency situation. ArcView provides the tools and capabilities to allow users to quickly and easily view areas with various combinations of data layers displayed, and with easy access to the attribute data for each data layer feature. In also allows for the integration of geographical data generated with one of their emergency management models, such as In-Land Winds (a program for modeling the path of hurricanes once they make land fall).

In addition to using the ArcView displays of GIS data directly, the emergency management staff will also produce output files from the ArcView displays for external distribution. These image products will be stored as GIF or JPEG files and will be transmitted directly to field users and county EMA offices. The interface to the external EMA users will take three forms depending on the network connectivity and computer resources of the external user. For those external EMA users on the WAN, having Internet connectivity, or having PCs with modems, the image files will be transferred using FTP in the first two cases and using modem protocol in the third case. The downloaded image files will then be viewed on the remote PCs using GIF and JPEG viewers. For those external EMA users without a PC or modem, fax copies can be sent.

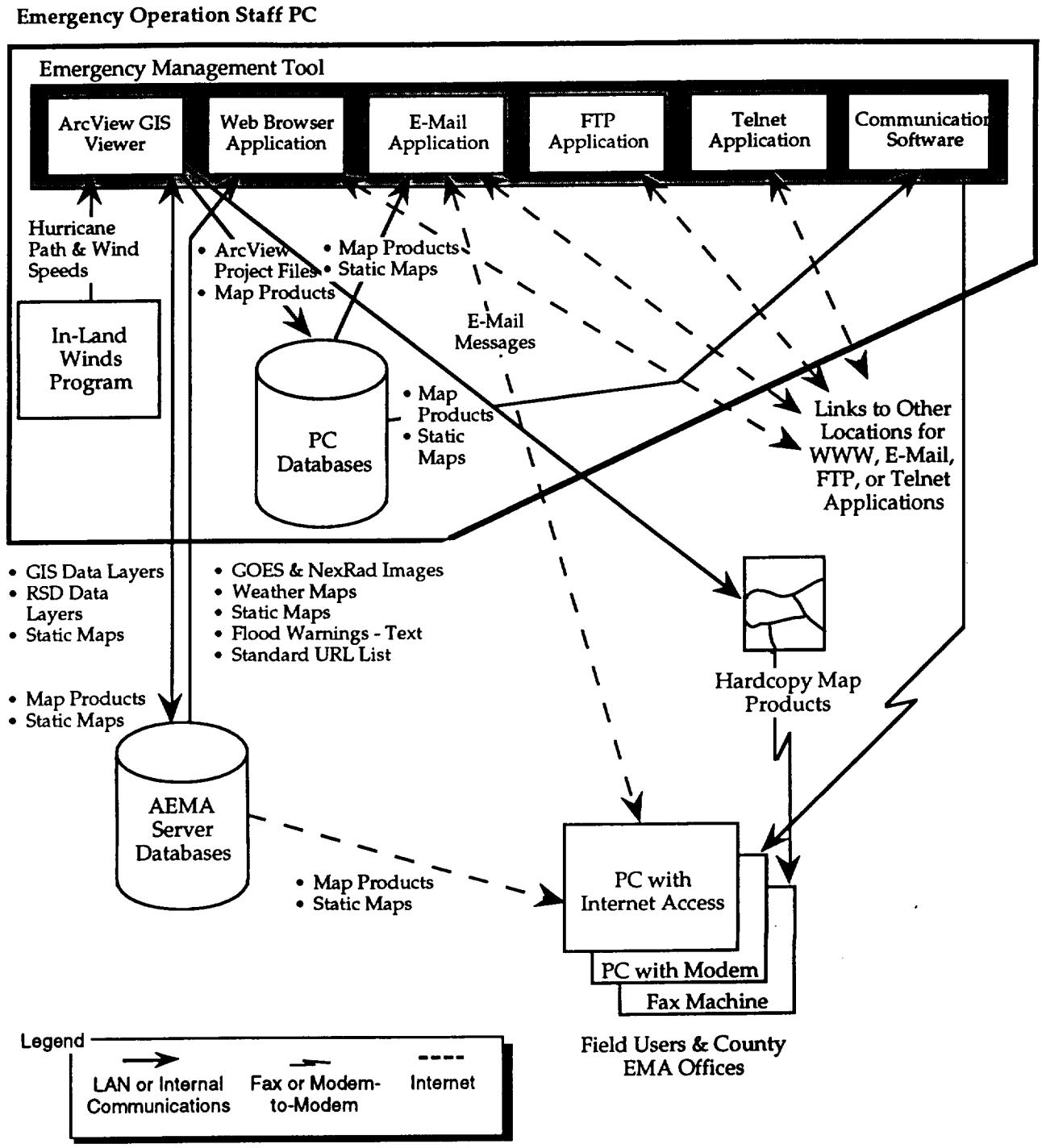

Figure 10. Emergency Operations Staff PC Interfaces

The other tools to be provided will consist of Internet and communication applications. A WWW browser will be included for linking into other sites for emergency-management related information or viewing the downloaded GOES and NEXRAD imagery on the SUN server. Specially tailored hotlist/bookmark files will be developed to facilitate the linking into the files on the server and the relevant external sites, based on the Internet site evaluation work previously performed by SENTAR and the emergency operations staff. An e-mail application will also be included for e-mail communications with other internal and external Alabama EMA staff, the Data Processing Staff, and other emergency management professionals either directly or through one of the relevant listservers. Also, an FTP application will be included for files transferred via Transmission Control Protocol/Internet Protocol (TCP/IP) networks and a Telnet application for linking into the DAACs to perform data queries. Lastly, the existing terminal communications software on the PCs will be used for modem communications with external users without Internet or WAN access.

OPERATIONAL OVERVIEW

This section provides a brief description of how the system prototype operates for three modes of emergency management. The modes addressed are: prediction, warning, and assessment. For each mode, the system operation is described in terms of the products that are generated to support that phase, how these products are generated by the EOC users, and when applicable, how the products are provided to the external users.

Prediction

Recall that the prediction phase is defined as anytime prior to the identification of an event that could trigger a flood. During this time period, no specific situation is being tracked that could generate a flood condition. Instead, activities focus on regional weather conditions and planning or preparation. For the prototype system, the weather monitoring and forecasting related products will be the prime focus. This will also be the time when contacts with other emergency management professionals using e-mail and e-mail based listservers will be used for general emergency management information exchanges.

For weather monitoring, the emergency operations staff will access weather forecasts, NEXRAD radar imagery, and GOES imagery to track storms. These data are all obtainable from the Internet using the Web browser or the FTP application and the Internet addresses in the Standard URL list stored on EOC Server. For the weather forecasts, links will be included for the NWS regional forecasts, local weather reports, and severe storm monitoring sites. The local weather reports will include area television station, some of which have their own doppler radars that provide more defined images of portions of the state. For example, Figure 11 presents a sample display from WHNT television's doppler radar that is accessible from their home page.

These weather products will aid in the tracking the severity and paths of storms through the state, and can provide indications of potential flood areas. Actual flood prediction modeling will be obtained from the NWS River Forecast Centers. These centers issue stage forecasts and crest forecasts for up to 3 days into the future and some crest forecasts up to a week in the future.

These forecasts are available on line from the NWS using the Web browser. The emergency operations staff will not only just monitor these forecasts, but they can be used in conjunction with the TVA lake and stream flow data also obtained on-line to make manual predictions for the Tennessee watershed.

For snow predictions, the National Operational hydrologic Remote Sensing Center (NOHRSC) provides on-line, near real-time data products of area coverage of snow and snow water equivalent. These products are georeferenced and can be brought directly into ARC/INFO for use with the data layers at the state level for this phase to help define specific areas of concern, should a warning be issued.

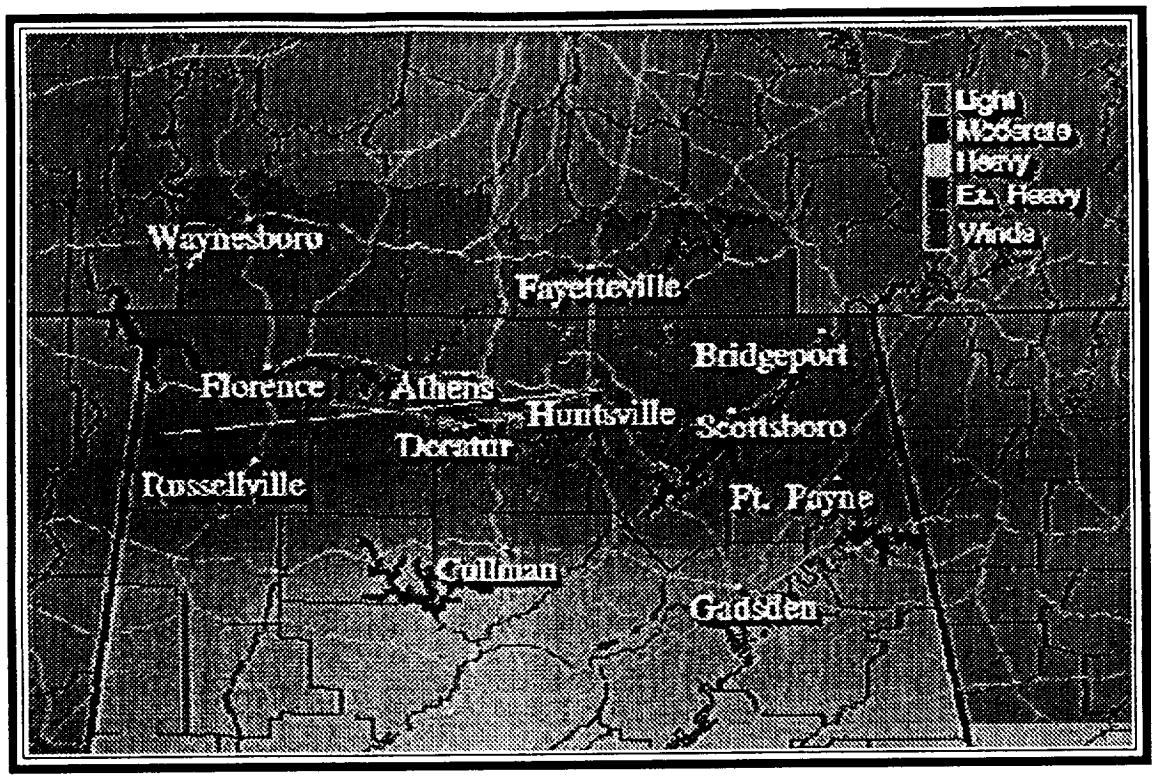

Figure 11. Sample Doppler Radar Display

Warning

For the warning phase, a specific condition has now been identified that will be monitored and emergency management resources will now be mobilized. As with the prediction phase, the weather monitoring using satellite and radar imagery as well as other agency forecasts will be used. Additionally, the flash flood predictions from the NWS will be obtained and incorporated into a data layer within the GIS. This data is only at the county lever currently, so the potential flood areas will be displayed as different shading within the county boundary (see Figure 12). Similarly, the precipitation and flood risk predictions from the FloodWatch system of the EarthSat Corp. will be accessed to show the potential risk of flooding at the county level (see Figure 13).

For hurricanes threatening Alabama, the emergency operations staff will also have the In-Land Winds program on their PCs that will be used to predict the in-land path of a hurricane and the associated winds that the counties in its path can expect [FEMA, 1995]. This program will be executed separately from the Emergency Management Tool, but the output files will be accessible to the Emergency Management Tool so that the hurricane path and wind speed data can be overlaid onto the ArcView GIS map display. Although In-Land Winds has its own state and county boundaries display capability (see Figure 14), the advantage to bringing it into ArcView will be that the emergency operations staff can use the other data layers to begin the response and recovery planning.

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SPRING FLOODING POTENTIAL OUTLOOK
NATIONAL WEATHER SERVICE SHREVEPORT LA
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BELOW AVERAGE POTENTIAL OF FLOODING IS EXPECTED THIS SPRING ACROSS THE FOLLOWING RIVER BASINS...MIDDLE RED RIVER...LITTLE RIVER IN SOUTHEAST OKLAHOMA AND SOUTHWEST ARKANSAS...MIDDLE OUACHITA RIVER...MIDDLE SABINE RIVER...AND THE UPPER NECHES RIVER.

DUE TO A DRY SUMMER AND AUTUMN OF 1995 ALONG WITH A RATHER DRY WINTER OF 1995 AND 1996...SOILS ARE SOMEWHAT PARCHED ACROSS SOUTHEAST OKLAHOMA...SOUTHWEST ARKANSAS...NORTH LOUISIANA...AND EAST TEXAS. ALL AREA RESERVOIRS ARE AT OR BELOW CONSERVATION POOL STAGES AS WELL... THUS THERE IS ADEQUATE STORAGE FLOOD STORAGE SHOULD HEAVY RAINFALL DEVELOP THIS SPRING.

ROSS

Figure 12. Sample NWS Flood Warning Prediction

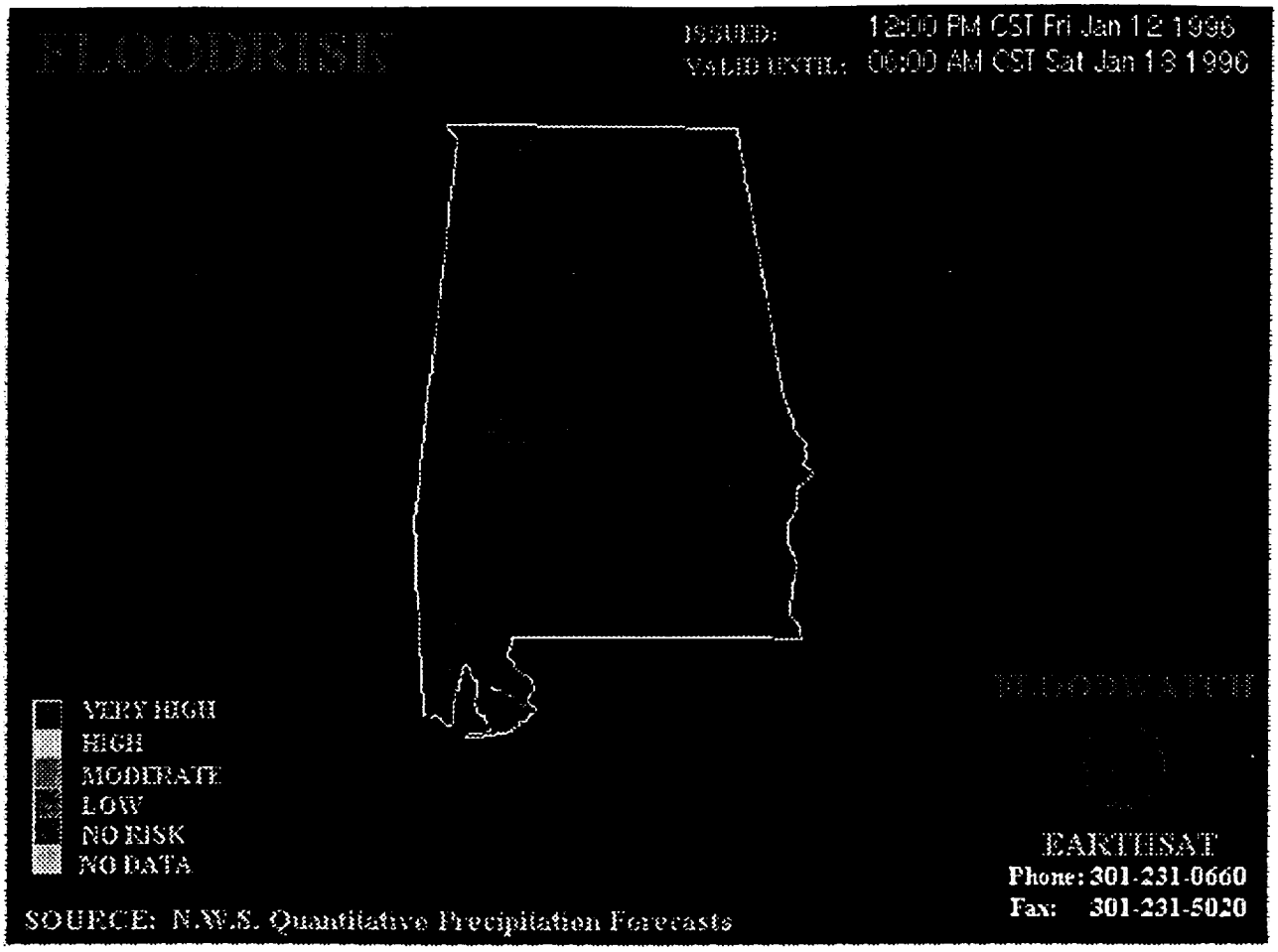


Figure 13. Sample FloodWatch FloodRisk Prediction Graphic

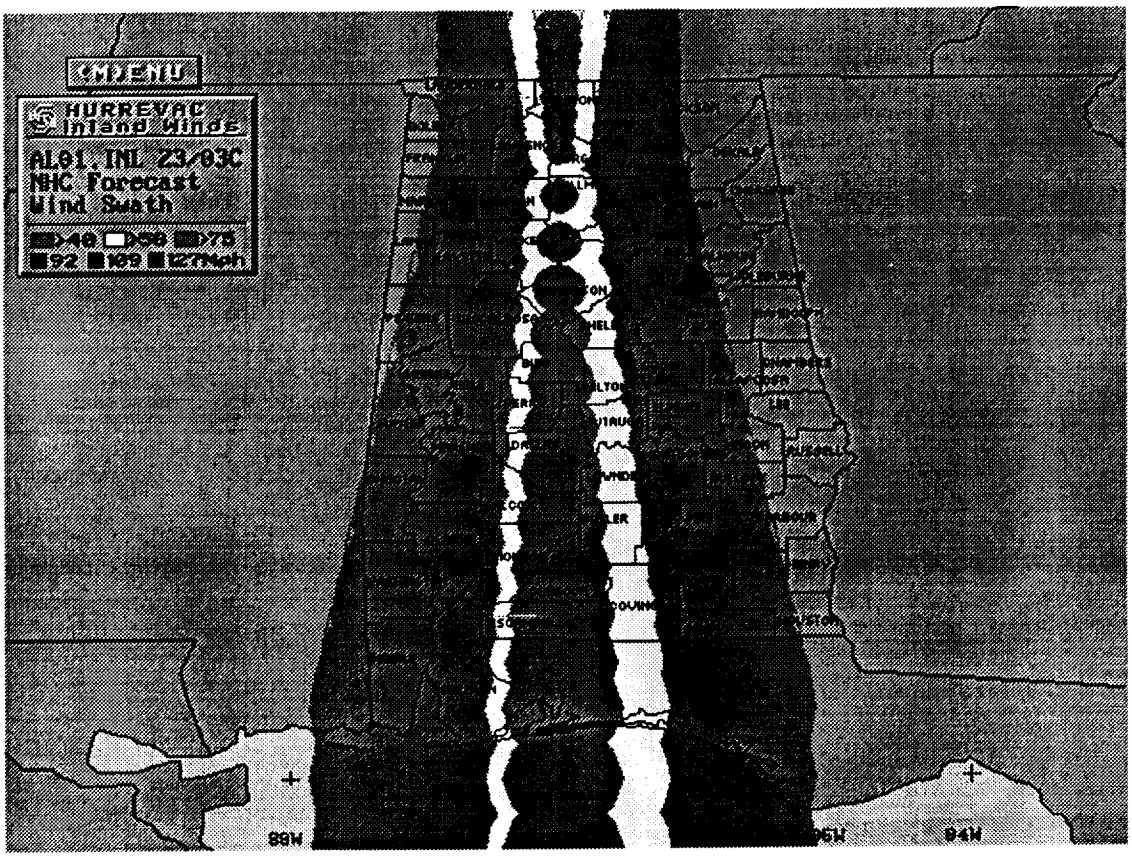


Figure 14. In-Land Winds Program Display Example

Initially, the emergency operations staff will use the state level GIS data layers to plot the projected storm track, but then they will begin to generate more detailed maps of coastal area predicted to be hit when the hurricane makes landfall. They will individually retrieve the GIS data layers from the EOC Server for the counties in the area of predicted landfall. They will also retrieve any backdrop images that maybe stored online and begin to build their maps for performing their mission. The specific data layers displayed on the individual PCs will vary due to the varied functions of the emergency operations staff. As appropriate, selected map displays from ArcView or the various Internet sources will be saved for export to field users and county EMA officials using the method appropriate for the intended users. Similarly, selected images will be passed on to the public information officer for inclusion in the WWW home page to inform the public.

During this process, the emergency operations staff will be in contact with the satellite remote sensing data providers and the Data Processing Center staff to determine the availability of archive images for backdrops, if none is available at the EOC, or of availability of current images of the area of interest. When useful images are identified, arrangements will be made to obtain the source data provide to the Data Processing Center to begin the necessary data processing.

This phase will also be when the emergency operations staff begin to estimate the specific areas of potential flooding using the county level flood predictions and the floodplain data layer. In addition, they will begin to start monitoring the TVA lake levels and stream flow data when the

potential flooding involves the Tennessee watershed. Next, they can add other data layers to look at potential impacts to roads, bridges, and population areas. Various views of the potential situation will be generated by combining selected GIS data layers and the available predictions and remote sensing data. Each view will be design to aid in a particular activity of the emergency operations staff. These views will provide information on potential impacts to areas and infrastructure system that will be used to alert the appropriate agencies and county officials and to plan for response and recovery efforts.

In a similar manner, the above steps can be used for any storm or event that is identified to potentially cause flooding, though these other storms and events may not yield the length of time in the warning phase as does the hurricane. Thus, not all steps may be completed before the flood begins and the staff transitions into the assessment phase.

Assessment

In the assessment phase, activity will focus on the use of ArcView and generation of map products. If it had not already been accomplished during the warning phase, a project file will be built for the GIS data layers for the counties of the affected area. Any archive satellite imagery will also be obtained and included to establish the none flooded view. Many of the activities that were described for the warning period again apply here, but now the focus will be on defining the extent of the flood and its impact on the population and the man-made infrastructure.

To accomplish this, current remote sensing data is needed. Any available images from past floods of the region may be useful in defining the potential flooded areas until current data can be obtained. These past flood images may include Landsat or SPOT images that can be obtained and processed at the Data Processing Center or that have previously been processed and are

therefore readily available. For more current data, the availability of new Landsat and SPOT images will be pursued, though the position of the satellites and the associated processing time limited the usefulness of this option at this time. For floods in the Tennessee watershed, the TVA lake and stream flow data will provide changes in river and lake levels that can be used with the DEM to estimate the flooded areas. The one option that is both current and available to all areas of the state is the use of aircraft photography. Photographs of flooded areas will be brought either directly to the Data Processing Center or to the Alabama EMA EOC where it will be digitally scanned and the file will be sent to the Data Processing Center via the Internet. (Note that the latter has a helicopter pad on site and access to Air National Guard support during emergency situations.)

The Data Processing Center will take the satellite or aircraft data and perform the necessary data processing to produce backdrop and land/water classification files for use in ArcView. When appropriate, GIS data layers will also be added to the processed remote sensing data to produce static maps. The static maps can be immediately used upon receipt at the EOC while the other files are being integrated with the GIS data at the EOC.

The emergency operations staff will use the newly created backdrop and land/water classification files within ArcView to perform specific analyses of the impact of the flood. These analyses include identification of the specific areas flooded, the population affected, the infrastructure systems impacted, and the potential economic impact. The emergency operations staff will use the suite of internal tools provided within the ArcView application to manipulate and analyze the displayed GIS data.

Many of the aircraft photographs may be unusable for GIS purposes because the quality of the photograph or the small area captured in the frame. These photographs may still have value from an emergency management perspective by clearly showing impacts to areas or structures. These photographs will not be sent to the Data Processing Center for processing, but instead will be captured digitally as is and assigned to a particular geographic location within ArcView.

The static maps, ArcView generated maps, and aircraft photographs will be produced for transfer to other emergency operations staff and other appropriate individuals. This will include the on-line or hardcopy transfer of these products to other emergency operations staff at the EOC, emergency management staff from other organizations that will work out of the EOC during emergencies (i.e., power, telephone, law enforcement officials), filed users, county EMA officials, and Federal EMA officials.

Finally, the remote sensing backdrops and land/water classification files created from the satellite images and aircraft photographs during the emergency will be archived at the EOC for future emergencies in the same area.

DESIGN DESCRIPTION

Emergency Manager's Tool

A major portion of the prototype system involves the collection and processing of remote sensing and GIS data to support the emergency operations staff. The Emergency Management Tool is where these various data sources are brought together, viewed, combined, manipulated, and exported by the staff to enhance the performance of their mission. As described earlier, the functionality they need to work with these data will be provided using various COTS software applications. What the Emergency Management Tool provides is a software product that creates an integrated interface for the emergency management staff to easily move between the COTS applications as if they were in fact one software product. The tool will provide access to the included applications through entries on the Windows menu bar and development of a tool bar with hot button icons. Thus, a user can click on the GOES satellite image menu item or hot button and have the image simply appear on the screen. The Tool will determine that the Web browser application needs to be started and know that the latest GOES image is stored on the EOC file server in a specific file. If the item selected is an external WWW site, then the Tool will initiate the connection to that site.

The tool will also simplify the data conversion processes that will be required to use various data files and to pass data files between application or for exporting. This is important since the software applications of the Emergency Management Tool import and export data in different formats that are not always compatible. The Tool will be configured to shield the user from data format transformation to the extent practical. In some cases this will require the execution of a utility application to perform the data conversion. When needed, the Tool will either execute the necessary application or simply open the utility if user inputs are required.

The COTS applications integrated through the Emergency Management Tool are listed below. With the exception of the GIS software, the remaining applications are listed under generic titles rather than by a specific vendor name. This is because only the GIS software has already been selected by the Alabama EMA and because there are several vendors with applications that will provide all the desired functionality. The final selection of the specific package to be used will be made in concert with the Alabama EMA during the software design review. Emergency Management Tool applications:

ArcView	– for GIS and remote sensing data viewing, combining, manipulation, map generation
Web Browser	– for viewing HTML files from Internet-based WWW servers
E-mail client	– for receiving and transmitting E-mail messages across the Internet using Post Office Protocol (POP)
FTP client	– for file transfers between internetworked computers using File Transfer Protocol

Telnet	– for remote log-ins to other computers to allow for execution of applications on the remote system from the local computer
Graphics Converter	– for performing file conversions and viewing between GIF, TIFF, JPEG, and Windows Bitmap file formats.

The user inputs for the Emergency Management Tool will be the selection of the application to execute via the menu bar or tool bar icons. Once inside a COTS application, the inputs will be those of the application selected. In most cases the user will supply the input values, however in some cases like the GOES image example, the inputs may be provided by the Tool for the user. Generally the program outputs will be those of the application being executed, as controlled by the user. The Tool's role will be to help direct where output files are to go (for storage or transport) and to aid in file transformations that may be required.

Imagery Mapping Utilities

The development of utilities are needed for the interface of the imaging software, MapiX, to the GIS software, ARC/INFO. SENTAR and NASA are using the MapiX imagery tool which is capable of manipulating satellite data provided by Landsat TM and MSS; Advanced Very High Resolution Radiometer (AVHRR), although it is currently not planned to be used directly; and SPOT; plus photography from any airborne platform. MapiX currently does not support output formats that are recognized by ARC/INFO that retain the georeferencing information.

The intention is to develop utilities that will convert the raster image and vector classification output files from MapiX into formats that can be used in ARC/INFO. The key element involved in this operation is the retention of the georeferencing data associated with the raster or vector data from distortion or even loss in the transition to the ARC/INFO application. Should there be insufficient information on the Mapix output format, the alternative approach is to transfer the files using the TIFF format and perform the georeferencing within ARC/INFO.

AML Utilities/Routines

The primary application used to create, edit, and manipulate the spatial data coverages will be the ARC/INFO GIS system. Through the use of this application, data coverages will be created with associated attribute data and then will be exported into a format that will be used with the viewing tool ArcView. The creation of data coverages and attribute data from source data files are accomplished through the use of the ARC Macro Language (AML). AML is the scripting language for data layer developers to communicate in the ARC environment. AMLs provides these users with the capability to tailor user interfaces and perform a variety of other tasks. In fact, most frequently performed data manipulation actions can be automated with the AML. ARC/INFO provides a directory of pre-written AMLs that can be used for normal operations, but some efforts to be performed for the prototype system will require both basic and sophisticated AMLs to be written to complete their tasks. Several of the AMLs that will be of use to the data layer developers are as follows.

Startup AMLs can provide the working environment defaults for terminal displays, mouse coordination, colors, work spaces and previously edited data source locations for each user of ARC/INFO. Startup AMLs will be tailored to suit the specific need of each data layer developer's intended use of ARC/INFO.

Data conversion AMLs will be a vital part of data coverage creation for the Emergency Management Tool. Most data sets to be gathered from remote FTP sites or provided by source media (tape, CD-ROM) are not in the ARC coverage format. These formats range from standard USGS Digital Line Graphs (DLG) and the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing System (TIGER) to state agencies data in flat file formats. AMLs will be developed to convert each of these data sets into ARC/INFO coverages.

Other miscellaneous AMLs will be developed to do general maintenance and clean up of data directories and ARC coverages. These AMLs will help in the alignment of county and state boundaries; node, polygon and points snapping; and error corrections to make the coverages accurate for quality visual representations within ArcView.

ArcView Avenue Scripts

As with other applications and tools being used by the Emergency Management Tool, ArcView is provided with the ability to be customized with its own scripting language called Avenue. This language is only available in ArcView version 2.0 and greater.

Avenue operates like the AML which resides within the ARC/INFO application. The Avenue language will be used to customize dialog boxes, remove and add menus, change button settings and tool icons for the specific needs of the emergency operations staff users of ArcView. Simple project startup/shutdown scripts for cleaning environments and opening and closing documents will be added with the capability of Avenue.

Through what is called Interapplication Communication, Avenue has the capability of communicating with other applications which will play an important part in the development of the Emergency Management Tool. Independent applications will interact with ArcView through the use of Avenue. These applications will work through the Remote Procedure Call protocol on UNIX systems or through Microsoft's Dynamic Data Exchange in the Windows environment. Popular desktop applications such as Microsoft's Visual Basic and Microsoft's Access database are among a few that Avenue can be tailored to work with, but other Emergency Management Tools being considered are programs such as the In-Land Winds.

Miscellaneous Utilities/Programs

Internet applications for Web browsing, File Transfer Protocol (FTP), and Telnet are among a few of the basic utilities that the Emergency Operations staff will rely on to complete a majority of disaster related work. These tools will be used to retrieve data on the most current source data from weather satellites, radars, and ground remote sensors. Through the development of automated UNIX shell scripts and DOS/Windows batch files that utilize these applications, data will be retrieved from specified sites, then updated on the source sever and stored on the Sun file server for access by the Emergency Operations staff. This will provide faster access to the data and will reduce bandwidth demands for the Alabama EMA Internet connection.

Some of the data files downloaded will undergo processing after downloading rather than simply being stored on the LAN. This will be done for extracting and formatting selected data from the data sets. UNIX power/programming tools such as SED and AWK will be used to create scripts that can extract keywords in text files retrieved from the remote sources. Examples are the text files created by the NWS for flood warnings or watches, and downloaded via the Web. Scripts developed in SED or AWK will look for key word matches (e.g., warning or watch), dates, and times and the referencing of Alabama and its counties. Once the script parses through the provided text file, an output report of the Alabama flood warnings and watches will be generated and stored for display by the Emergency operations staff. In addition, a data table of the counties under flood warning will be created and stored for access by ArcView. ArcView will use the data values in this data table to populate the data layer for counties under a flood warning in the Emergency Management Tool. The dates and times of the warning will be provided as attributes to the flood warning data layer.

DATA INTERFACES

This section describes the external and major internal interfaces for the system prototype source data. Each subsection describes one of the source data types in terms of the source, the transfer media into the system, the intended use of the data with in the system, and the data's path through the system elements. The description of the data's passage through the system elements

focuses on the data transformations and processing that will be performed on the data. For some data types, there will be one than one path the data may take through the system. These cases are identified along with the factors used to select a specific path through the system.

The source data are grouped into four major categories: remote sensing, remote sensing products, emergency management, and GIS. The remote sensing category consists of the Landsat and SPOT imagery, airborne photography, and TVA Automated Lake Information. Some of these will be integrated into the GIS, however for the following presentation the GIS data is limited to those non-remote sensing data necessary to generate the data layers identified in TABLE 1. The remote sensing products are the Internet-accessible text and images produced from remote sensing data or that integrate remote sensing data with GIS data. These include: GOES images, NEXRAD images, NWS forecasts, NOHRSC snow cover images, and FloodWatch flood predictions. The GIS category includes the various source data for the GIS data layers identified in TABLE 2. The emergency management category currently consists only of e-mail traffic from other emergency management professionals and organizations and from emergency management and disaster related listservers.

Remote Sensing

Landsat. Archival and current Landsat TM and MSS images will be acquired from the EDC. These data will be transferred to the Data Processing Center via magnetic tape in most cases. Limited data set requests may yield files small enough to be effectively transferred via the Internet using FTP. The Landsat archival data will be used for the backdrop maps or to define the non-flood water boundaries for temporal hydrology analyses. The current Landsat data will be used to create the land/water classifications for flood delineation and to define the flood water boundaries for temporal hydrology analyses.

The source data from tape will be extracted off the tape onto on-line storage for processing via MapiX. Similarly , the source data retrieved via FTP will downloaded and stored for MapiX processing. The processing with in MapiX will convert the raw Landsat files of individual band pixel values into image products of multi-band images and land/water classifications. These files are then reformatted for importing to ARC/INFO. These files may also be integrated with some GIS data within MapiX and then exported in GIF format as static maps. The ARC/INFO formatted files will be transferred to the Alabama EMA EOC via the Internet or via magnetic tape depending on the size of the files and the urgency of the delivery. Generally files that can be transferred in several hours or less will be sent via the Internet. The static maps will all be sent via the Internet as they will generally be on the order of under a 100 Kbytes.

All Landsat data products received at the EOC by tape or Internet will be stored on the EOC file server until accessed by the emergency operations staff from their PCs using ArcView for the ARC/INFO formatted image files and the Web browser or graphics viewer applications for the static maps. The static maps may be redirected to the field users, county EMA offices, or the home page for public access via the Internet. Where Internet connectivity does not exist, these maps will be sent via modem communications software or fax. From ArcView, the emergency operations staff will also produce map outputs that can be sent to field users, county EMA offices, or the home page for public access like the static maps.

SPOTView Imagery. Archival and current SPOTView panchromatic and multispectral images will be acquired from the SPOT Image Corp. These data will be transferred to the Data Processing Center via magnetic tape. As with the Landsat images, the SPOTView archival data will be used for the backdrop maps or to define the non-flood water boundaries for temporal hydrology analyses. The current SPOTView data will be used to create the land/water classifications for flood delineation and to define the flood water boundaries for temporal hydrology analyses.

The processing of the SPOTView data will be essentially the same as the Landsat data, except that SPOTView images can also be obtained in an ARC/INFO format. Some of the acquired

SPOTView data will be obtained in this latter format to demonstrate the ability to bypass the MapiX processing. In either case, the passage of the data images through the system after the Data Processing Center will be the same as for the Landsat data described above.

Airborne Photography. Due to the limitations of availability, cloud cover, time, and cost associated with high resolution satellites images from Landsat and SPOT, airborne photography offers a feasible alternative for visual imagery source data. Several sources for the airborne photography will be considered in the prototype system. These include high-quality photography produced by commercial aerial photographers, still photography produced by emergency management personnel, and other still photography produced by local photographers. In each case, a printed copy of the film images will be scanned to produce a digital data file for processing at the Data Processing Center. The hardcopy photos will either be physically transported to the Data Processing Center for scanning or will be brought to the Alabama EMA EOC for scanning, and then will be sent to the Data Processing Center via FTP on the Internet. Alabama EMA may acquire a digital camera in the near future. If this camera is acquired in sufficient time, it will be used in the prototype demonstrations as an added source of aircraft imagery that bypasses the scanning process.

Once a digital file is produced and transferred to the Data Processing Center, the image processing will begin using MapiX. The photographs will be generally of lower quality and usability than the satellite images since they may be acquired using simple equipment. Thus, one of the initial processes to be performed is a determination of which photographs are of sufficient quality to be georectified. Those deemed unsuitable for georeferencing may still have value simply to visualize a disaster area. These photographs will be retained in digital form and sent to the Alabama EMA EOC just like the static maps. For those photographs suitable for georeferencing, the processing will be similar to that performed on the satellite images. Two significant differences in the aircraft and satellite images are that the former cover a much small area on the ground and have more distortion across the image due to a greater incidence angle of the camera to the ground. To compensate for the smaller area coverage, great use of mosaicing will be required. The greater distortion will be unavoidable, however, hopefully it will not negate the benefits of increased availability and faster response time of the aircraft photographs.

The photographs that can be successfully processed in MapiX will then follow the same paths as described for the Landsat images. Those that could not be processed will be sent to the EOC as simple GIF images, but will be linked geographically to the processed images so that they can be used for visual interpretation by the emergency operations staff.

NEXRAD. Radar displays for the NWS NEXRAD radars for several cities in or around Alabama are available on the WWW with political boundaries for geographical reference. These are provided by the Intellicast Corp. and are updated every hour. The radar displays are provided as GIF images. Figure 15 provides an example of one of the NEXRAD images available on-line. These images will be retrieved and stored on the EOC file server the same as the GOES satellite images are stored. The images will be retrieved by the emergency operations staff via the Emergency Management Tool, and will be primarily used for weather monitoring. The transporting and usage of the NEXRAD images within the system prototype will be exactly the same as described for the GOES satellite images.

Tennessee Valley Authority Automated Lake Information. The Tennessee Valley Authority provides information on lake levels, streamflows, dam releases, and rain rates within the Tennessee Valley. These data are derived from remote sensors located throughout the Tennessee watershed. Figure 16 presents a sample of the available data. Currently, TVA provides this information on an electronic Bulletin Board System and is updated four times per day. TVA plans to make the data available to state EMA's via FTP across the Internet at an unspecified date in the future. This data will be accessed after each update time via scripts on the EOC server. The downloaded data will be stored as is for viewing by the emergency operations staff and will be processed within Processing Utilities on the server for extraction of the selected data items for

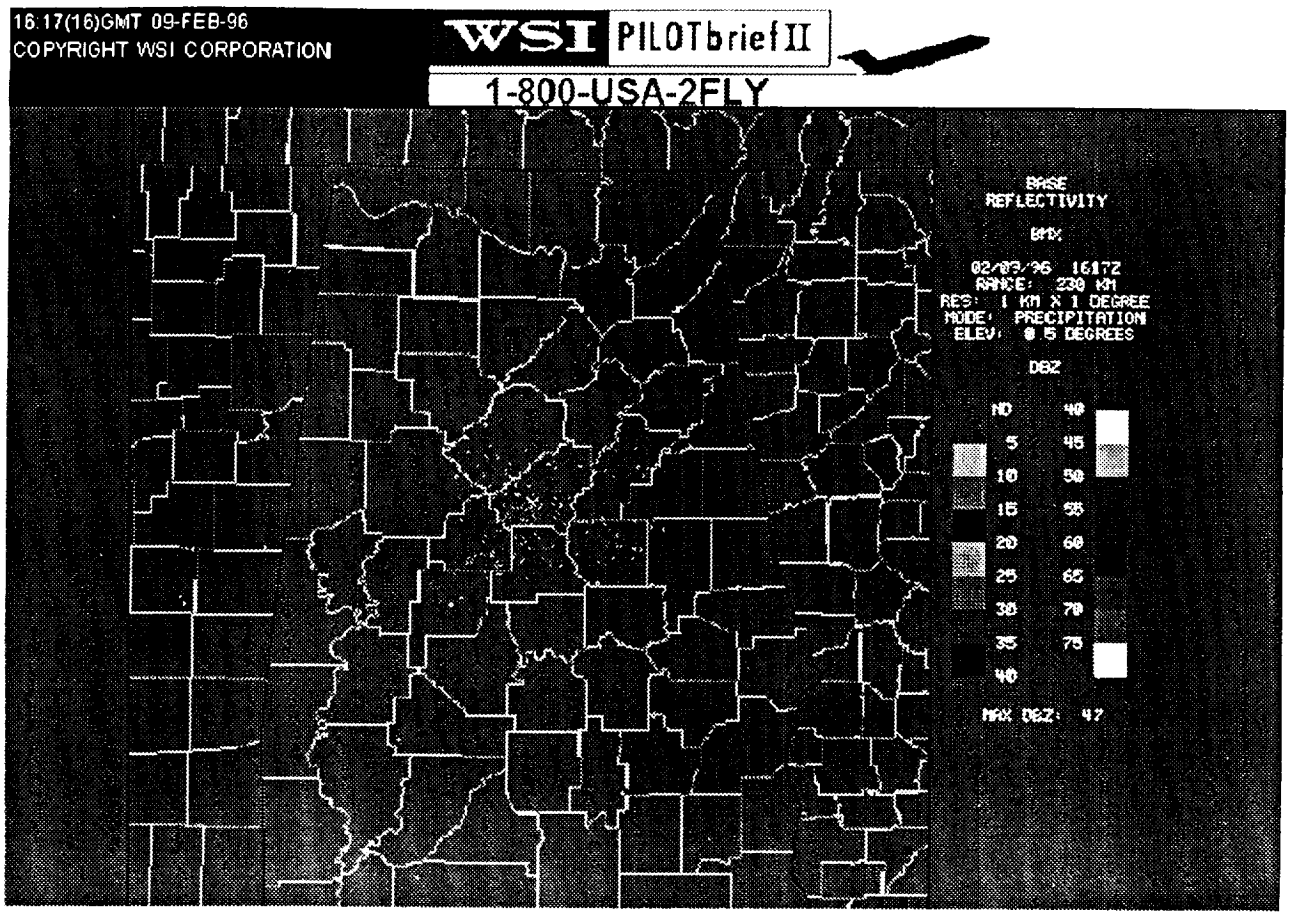


Figure 15. Example of an On-line NEXRAD Image

the GIS database. Using the Emergency Management Tool, the stored source data file will be viewable as a simple display of the information in text format and the GIS-integrated data will be accessed as attribute data in the Hydrology and Dams data layers.

Standard URLs. A standard list of URLs will be built of key Web, FTP, and Gopher locations. This list will be centrally maintained, and is separate from any stored URLs (i.e., bookmarks or hotlists) that the emergency operations staff individually create. These locations will be those that the staff will visit themselves versus the sites where data will be retrieved and stored locally on the LAN. The emergency operations staff are exploring various emergency management and weather related Internet sites to determine the initial set of sites to be on the Standard URL list. Sites deemed valuable, but considered for agency-wide use will be left for inclusion on personal URL lists on specific PCs. The list of URLs compiled by the end of the fifth milestone period will be used for the initial Standard URL list. At that time, these URLs will be arranged in a set of folders. The specific titles of the folders and the grouping of the URLs in the folders will be based on inputs from the emergency operations staff.

Remote Sensing Products

GOES Weather Data. GOES produces hemisphere views of the earth displaying cloud coverages in the visible and infrared bands. See Figure 17 for an example. The GOES images are integrated with political boundaries to enhance location recognition and stored on-line in GIF format by the University of Wisconsin. The coarse resolution, 1 km, provides insufficient detail

Guntersville, Wheeler
1) Previous Menu
2) Download data to local PC
3) View/display data
[Download/View] Select function> 3

TENNESSEE VALLEY AUTHORITY RESERVOIR OPERATIONS
HOURLY WATER RECORD SHEET 8 retrieved 19960217 13:05

Friday, February 16, 1996

Guntersville	Wheeler
MAX EL 595.00	MAX EL 556.00
MIN EL 593.00	MIN EL 550.00

HR	Guntersville HEAD ELEV	Guntersville TAIL ELEV	Guntersville TOTAL DISCH	Wheeler HEAD ELEV	Wheeler TAIL ELEV	Wheeler TOTAL DISCH	HR
13	593.44	562.75	95660	552.52	507.56	113250	13
14	593.49	562.42	86310	552.53	507.54	112875	14
15	593.53	562.17	82920	552.52	507.53	112875	15
16	593.50	561.91	82590	552.53	507.52	113250	16
17	593.56	561.76	82520	552.53	507.57	112875	17
18	593.64	561.64	82530	552.53	507.51	112875	18
19	593.66	561.55	82590	552.55	507.55	113250	19
20	593.72	561.44	82800	552.55	507.51	112875	20
21	593.75	561.37	82850	552.55	507.46	112875	21
22	593.76	561.35	82840	552.55	507.51	112875	22

next page[RETURN] quit[q]:

23	593.80	561.27	82900	552.55	507.46	112875	23
24	593.83	561.17	82930	552.55	507.50	112875	24

Saturday, February 17, 1996

1	593.84	561.16	82960	552.57	507.05	103500	1
2	593.82	561.08	82910	552.57	507.10	104250	2
3	593.86	561.03	82930	552.57	507.10	104250	3
4	593.87	561.02	82930	552.57	507.16	103875	4
5	593.88	560.97	82960	552.57	507.06	104625	5
6	593.87	560.93	82960	552.55	507.16	104250	6
7	593.87	560.92	83030	552.49	507.63	109125	7
8	593.89	560.91	83070	552.48	507.65	114375	8
9	593.90	560.89	83100	552.45	507.69	114750	9
10	593.87	560.82	83050	552.38	507.72	114000	10
11							11
12							12

(EOF)next page[RETURN] quit[q]:

Figure 16. TVA BBS Data Sample

for detecting flood events. However, the data have a high image rate, every 30 minutes, and are available on-line very quickly after reception from the satellite so they provide an excellent weather monitoring capability, as well as gross views of large-scale flooding. Thus, the images will be used to support the prototype for near real-time weather monitoring and will not be integrated with the other GIS data layers.

The GOES images will be downloaded by the EOC server as soon as they are available. Note that the images are available from several sites in addition the primary archive at the University of Wisconsin, thereby providing alternative sources in event of congestion at a primary site. The current image will then be stored on the server in a location that will be designated for the current GOES image, and the previous current GOES image will be renamed and archived for a few days. When the emergency operations staff selects current GOES image from the Emergency management Tool, the software will access the image stored in the current GOES image location and execute an imager application to view the file. For archived GOES images, the emergency operations staff will be prompted for the data and time from a displayed list to retrieve the appropriate image. These displayed images can then be exported in the manner of the static maps to field users and county EMA offices.

National Weather Service Forecasts. The NWS provides weather and flood forecasting services over the Internet. This information is clearly useful in its present form and is easily retrievable off the Internet via a Gopher server as text files. TABLE 3 presents a list of the specific products that are provided for the state of Alabama by the NWS. These products are updated at different intervals from hourly to weekly. Automated scripts will be used to download the files as they are updated so that the most current data is on the EOC. Once downloaded onto the server, they will be stored as is. The flood warning data files will also be sent to the Processing Utilities for extraction of the selected data items for the GIS database in the same manner as the TVA data. From with the Emergency Management Tool, the stored source data files will be viewable as simple displays of the information in text format and the GIS-integrated flood warning data will be displayed as color-coded counties within the county boundary data layers.

TABLE 3. NWS ON-LINE WEATHER PRODUCTS

Agricultural Weather Advisory	Coded Cities Forecast
Alabama Temperature Projections	Alabama Weather Summary
Weather Summary	Area Forecast Discussion (Mobile)
Climatic Summary (Auburn)	State Forecast Discussion (Birmingham)
Climatic Summary (Birmingham)	Alabama Zone Forecasts
Climatic Summary (Mobile)	State Forecast for Alabama
Climatic Summary (Montgomery)	Public Information Statement
Short-Term Forecast (Birmingham)	River Forecasts
Short-Term Forecast (Mobile)	River Summary for Alabama
Hourly Weather Roundup	Daily River and Precipitation Data
Surface Aviation Observations	Flash Flood Guidance (ATL)
State Maximum/Minimum Temperature and Precipitation Table	

The NWS is also implementing extended forecasting through extension of the NOAA WARFS program for forecasts up to weeks prior to a flood, which may be available during the remainder of this project.

National Operational Hydrologic Remote Sensing Center. The National Operational Hydrologic Remote Sensing Center (NOHRSC), operating under the Office of Hydrology of the NWS, creates and distributes hydrologic products using remote sensing data. These include satellite aerial extent of snow cover and snow water equivalent, airborne snow water equivalent, airborne soil moisture, and average surface air temperature. Multi-source satellite (AVHRR and GOES), point (i.e., manual and telemetered observations), and line (i.e., airborne gamma radiation surveys) data are combined in the Operational Product Processing System (OPPS) to produce the various NOHRSC products. OPPS exports the products as raster files in several common GIS, plus as a GIF image with overlaid political boundaries for viewing via the WWW. All formats are available via the NOHRSC home page, and are provided on-line at least twice weekly, and some daily.

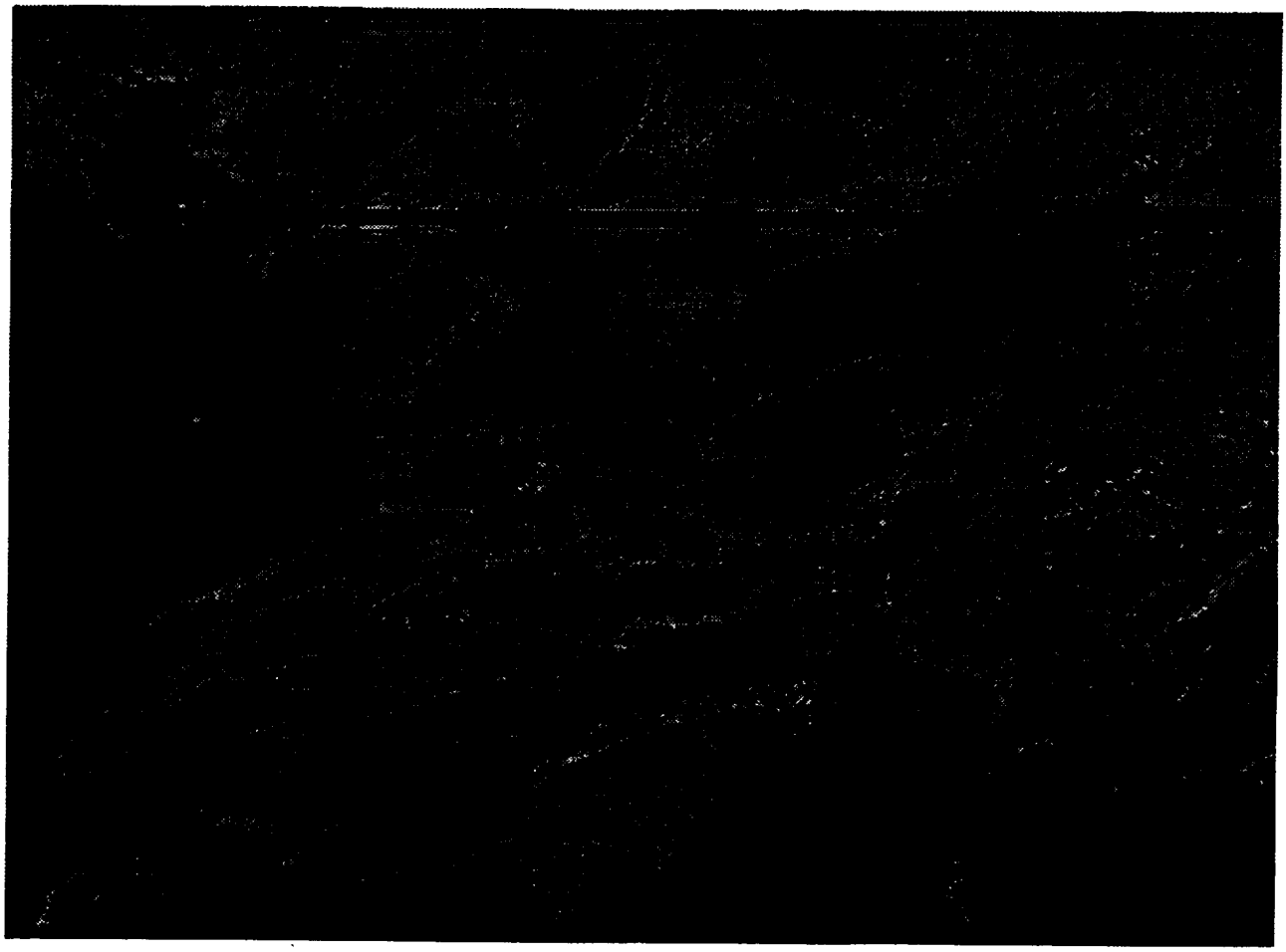


Figure 17. Example of a GOES GIF Image

For use in the prototype system, the appropriate files will be accessed and downloaded to the EOC server. These files are retrievable in ARC/INFO format which will limit the processing required. An AML script will still be needed once the files are on the server, prior to the files being accessible to the emergency operations staff. The GIF image files will also be downloaded and stored centrally for viewing by any of the emergency operations staff. The specific products to be used for the prototype system are the aerial extent of snow cover, the snow water equivalent, and the surface air temperature. The GIF format versions of these products are shown in Figures 18 through 20, respectively.

FloodWatch. FloodWatch is a set of flood prediction and response tools. It consists of three major products. These are FloodCast, Floodplain Management Tools, and Watershed Modeling Systems. FloodCast is a suite of two on-line flood forecast maps produced by the Meteorological Division of Earth Satellite Corporation (EarthSat): FloodThreat and FloodRisk. Floodplain Management Tools are a full complement of satellite imaging, remote sensing, and GIS applications used by the EarthSat staff to perform flood impact assessment and mitigation. Watershed Modeling Systems is a terrain-watershed modeling system under development by the Engineering Computer Graphics Laboratory of Brigham Young University. EarthSat is an applications development partner to Brigham Young University for applications in the Watershed Modeling Systems. The current product developed under this partnership is MIKE-11 Flood Forecasting System. MIKE-11 is a dynamic, menu-driven modeling tool for the detailed design, management, and operations of simple and complex river and channel systems.

For the prototype system, only the FloodCast portion of the FloodWatch program will be used. As mentioned earlier, the two tools within FloodCast are FloodThreat and FloodRisk. FloodThreat produces a color map indicating by county how much rain is required over any 3-hour period, within the next 24 hours, to cause flooding within the county. A graduated color scale is used to designate the amounts of rainfall needed, in half inch increments, to potentially cause flooding. The FloodThreat maps are generated for the conterminous United States and for seven southeast states, which include Alabama. The maps are available from the FloodCast home page as GIF images. Figure 21 is an example of the FloodThreat map for the U.S.

The FloodRisk tool combines the FloodThreat output with the expected 3-hour precipitation forecasts to produce a color map indicating by county the level of risk for flooding within the next 24 hours. Floodrisk color codes each county according to one of five flood danger levels from *Very High* to *None*. The maps are updated up to four times daily based on weather and flood conditions and are also provided as GIF images. See Figure 22 for an example.

Both of these FloodCast product outputs will be incorporated into the prototype. Initially, these will be simply downloaded periodically and stored on the Alabama EMA server for downloading to individual PCs by the emergency operations staff. Later they the county values will be converted to ARC/INFO format for displaying within ARC/INFO or ArcView as separate data layer.

GIS

For the purposes of this section, the GIS data sources will be grouped into two categories based on the similarity of the data processing and transporting through the system of the source data. These categories are those data sets processed at the Data Processing Center and those processed at the Alabama EMA EOC. Within each category, the general data processing and transporting path through the system will be described, with each specific data source being discussed only where it deviates from the general data processing and transporting.

Data Processing Center. The source data handled by the Data Processing Center will consist of consist of data files from the U.S. Census Bureau (TIGER), the U.S. Geological Service (USGS), such as DLG and DEM, U.S. Corps of Engineers, Federal EMA, Defense Mapping Agency Digital Aeronautical Flight Information File, and Military Installations. Most of the data will be already automated and will be provided on tapes or CDs. The source tape will be loaded into the

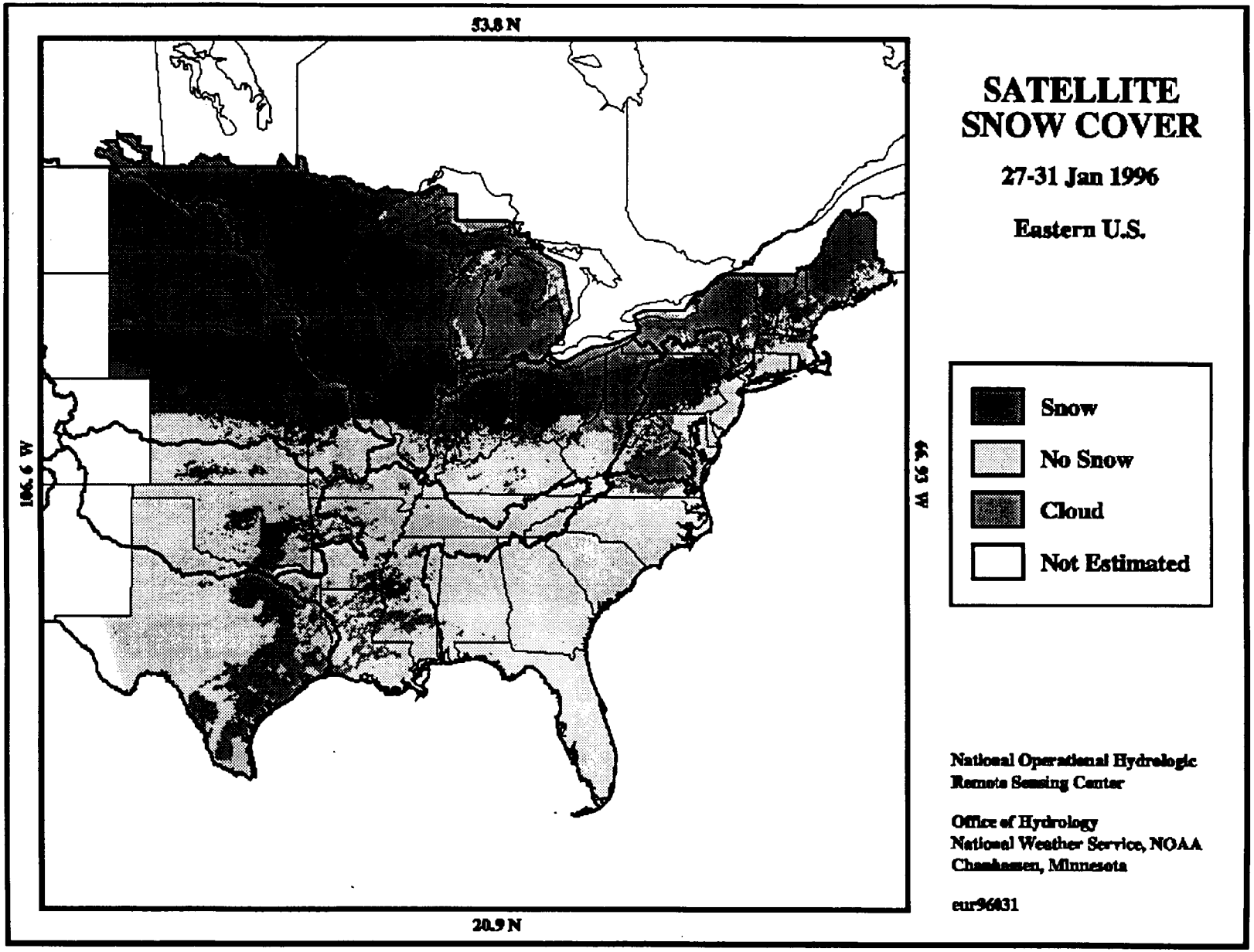


Figure 18. NOHRSC Aerial Extent of Snow Cover

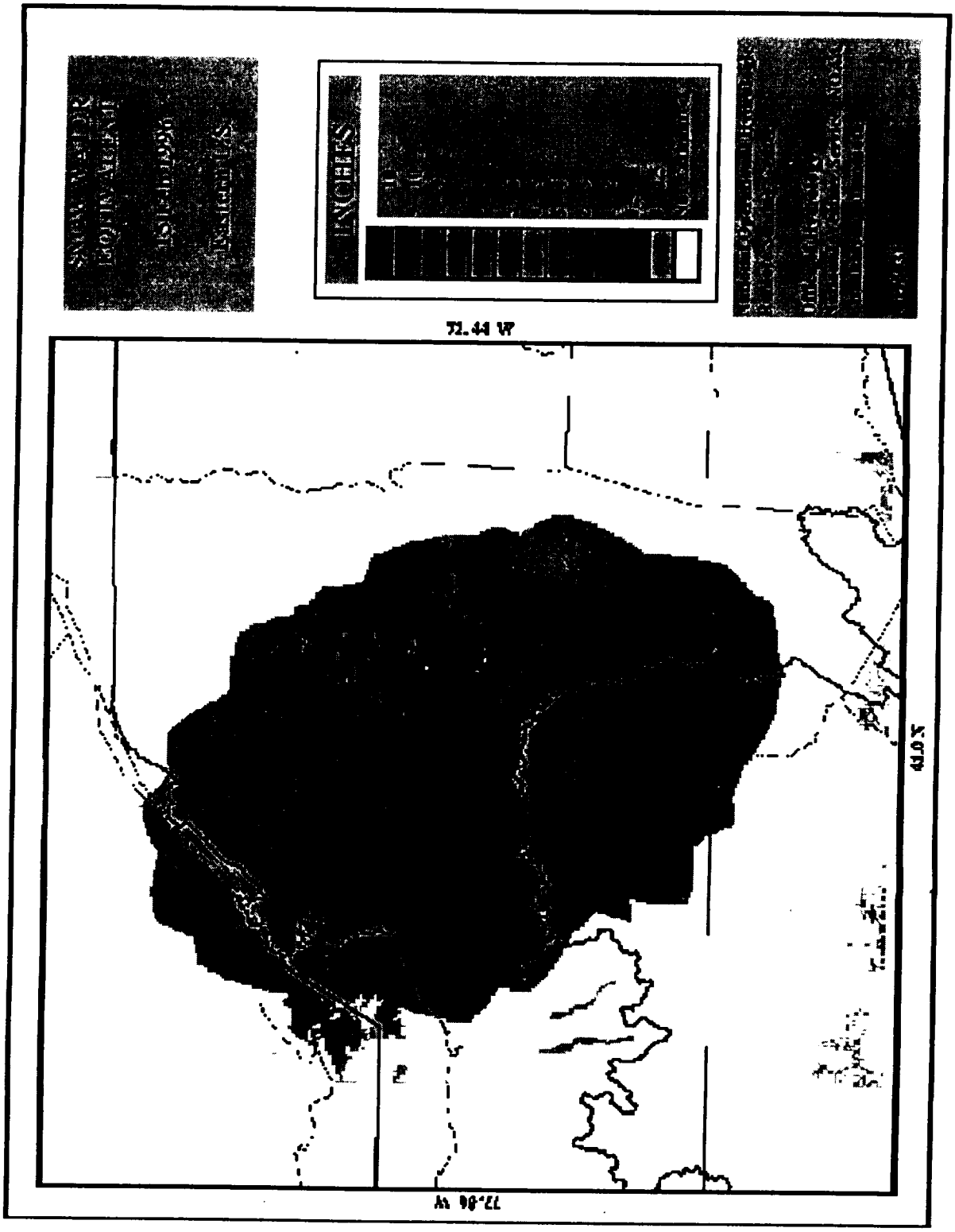


Figure 19. NOHRSC Snow Water Equivalent

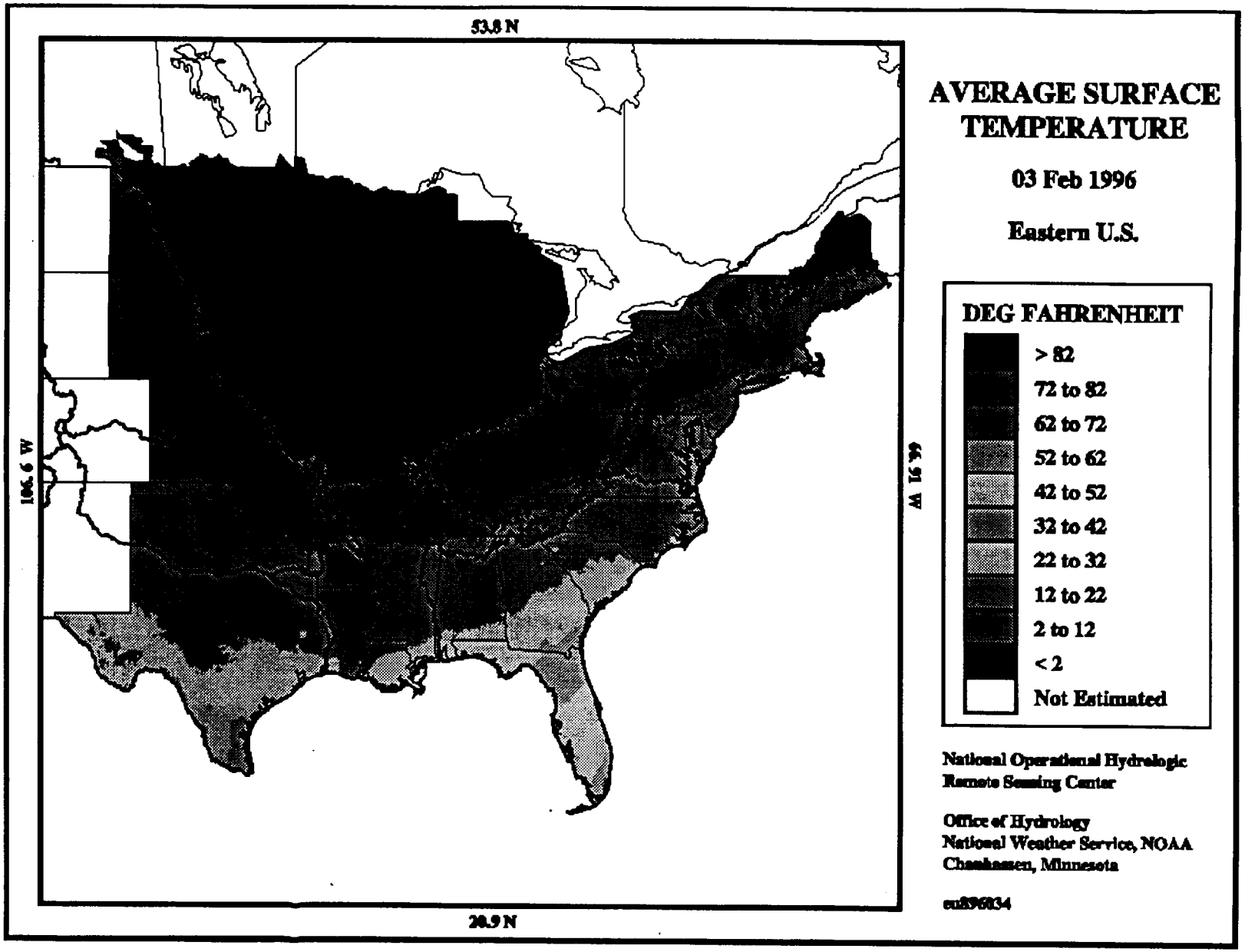
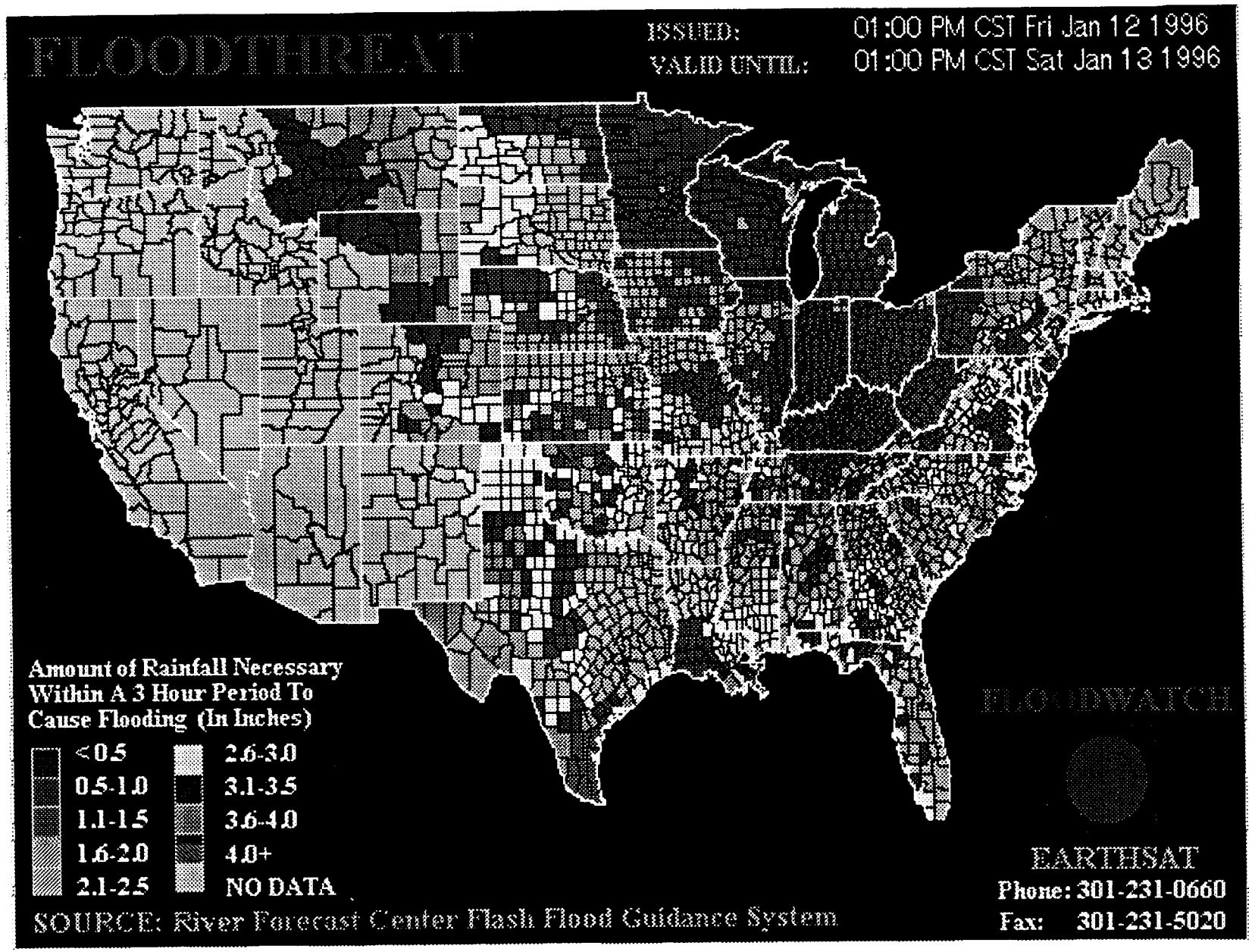
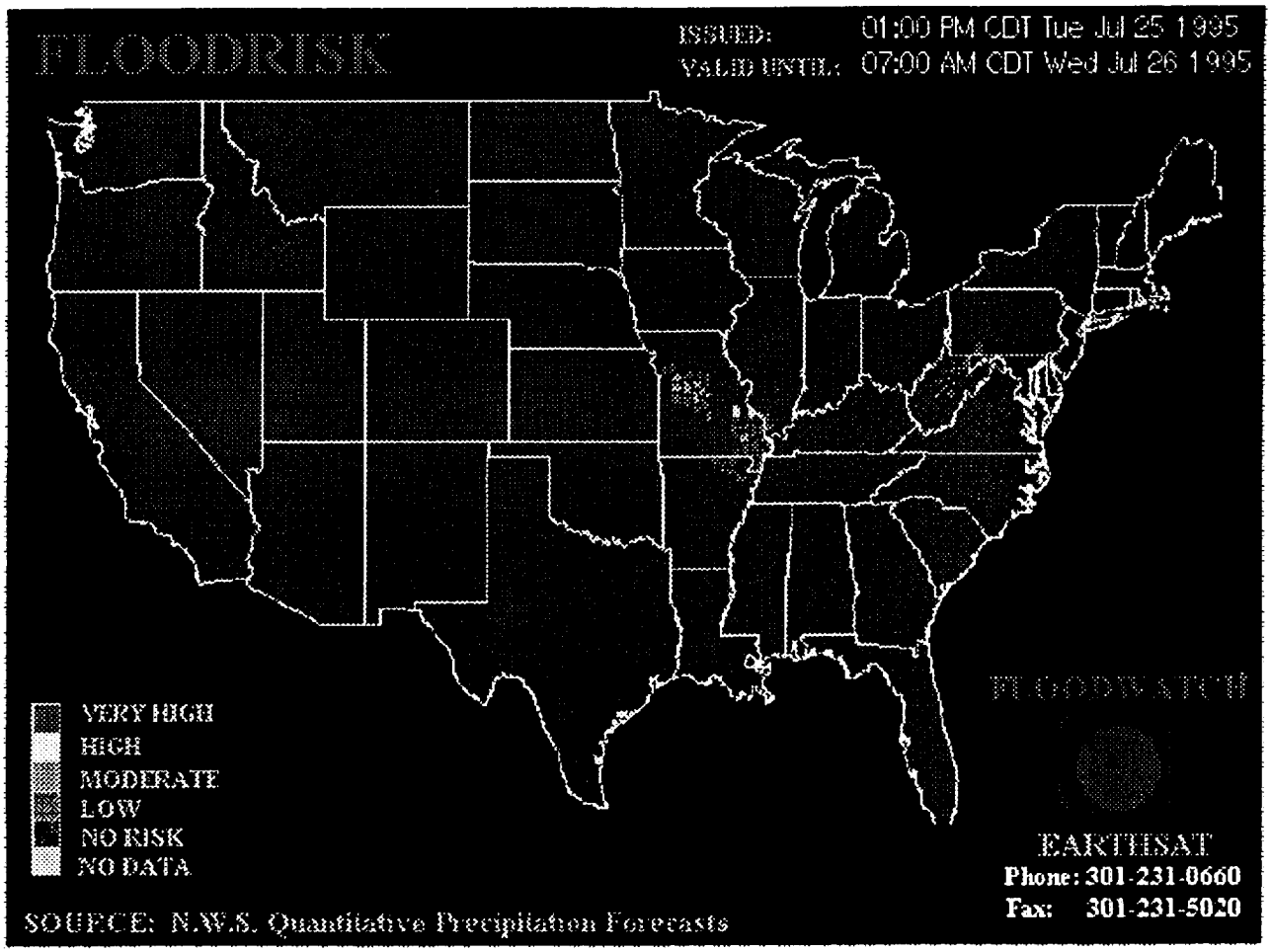


Figure 20. NOHRSC Surface Air Temperature



Source: FloodCast home page "http://www.earthsat.com/flood/maps/ffgusa.gif"

Figure 21. Sample FloodThreat map for the 48 Conterminous United States



Source: FloodCast home page "http://www.earthsat.com/flood/maps/riskusa.gif"

Figure 22. Sample FloodRisk map for the 48 Conterminous United States

system and will be processed using either prewritten or newly developed AML scripts to correct reformat, create specific data layers and attributes, and produce ARC/INFO coverages. With the exception of the TIGER line files, all the data sources provide data for one data layer. These data represent land or man-made features as lines, point, or polygons.

The completed data coverages will be exported to the Alabama EMA EOC via magnetic tape for the initial GIS database development. At the EOC, the data will be stored on the central server in the GIS database. These data coverages will then be accessed by the emergency operations staff via the Emergency Management Tool for use in the ArcView tool. From there, the staff can display various data coverages, with or without remote sensing data, and extract information visually or create output products for electronic transfer or hardcopy output.

Alabama EMA EOC. The source data handled by the Alabama EMA EOC will consist of all the infrastructure data from state agencies and the remote sensing data and data products retrieved from the Internet. In the former categories are the data from the Alabama Department of Environmental Management, Alabama Conservation Department, Alabama Department of Public Health, Alabama Department of Transportation, Alabama Power Commission, Alabama

Commission for the Aging, Alabama Fire College, the Historical Commission, and Alabama EMA's own files. With the exception of the Alabama Department of Transportation, all the other data sources only have the data in printed form. Thus, these data will have to be hand entered into the computer via the keyboard for text based source data or via a digitized for map based source data. Once onto the system, the raw data files will be processed using various AML scripts to produce the desired data layers and attributes. In the latter case, near real-time remote sensing data and data products will be obtained on-line from TVA, NWS, NOHRSC, and EarthSat. These involve downloading of text and image files from WWW and FTP servers. Once on the system, each will be processed to extract the data to be used to populate a data layer or the attribute fields of a data layer.

The completed data coverages and attributes are stored on the server in the GIS database with the GIS data layer coverages processed at the Data Processing Center. From there they are accessed by the emergency operations staff via the Emergency Management Tool for use in the ArcView tool, as described earlier. One difference for viewing and using the data layers incorporating near-real time remote sensing data is that the data layers need to be reselected each time the source data is updated. These data will be changing one or more times daily, unlike the other data layers where the source data will not change over the course of a specific disaster effort. It will also be necessary to have a convenient method of notifying the user of the effective date and time of the source data needs for the emergency operations staff to correctly use the data. This will be accomplished by modifying the data layer table of contents for an ArcView view using ArcView Avenue scripts to display the date and time each time the data layer is reselected. Figure 23 shows a sample ArcView screen display with the time and date for the Flood Warning data layer.

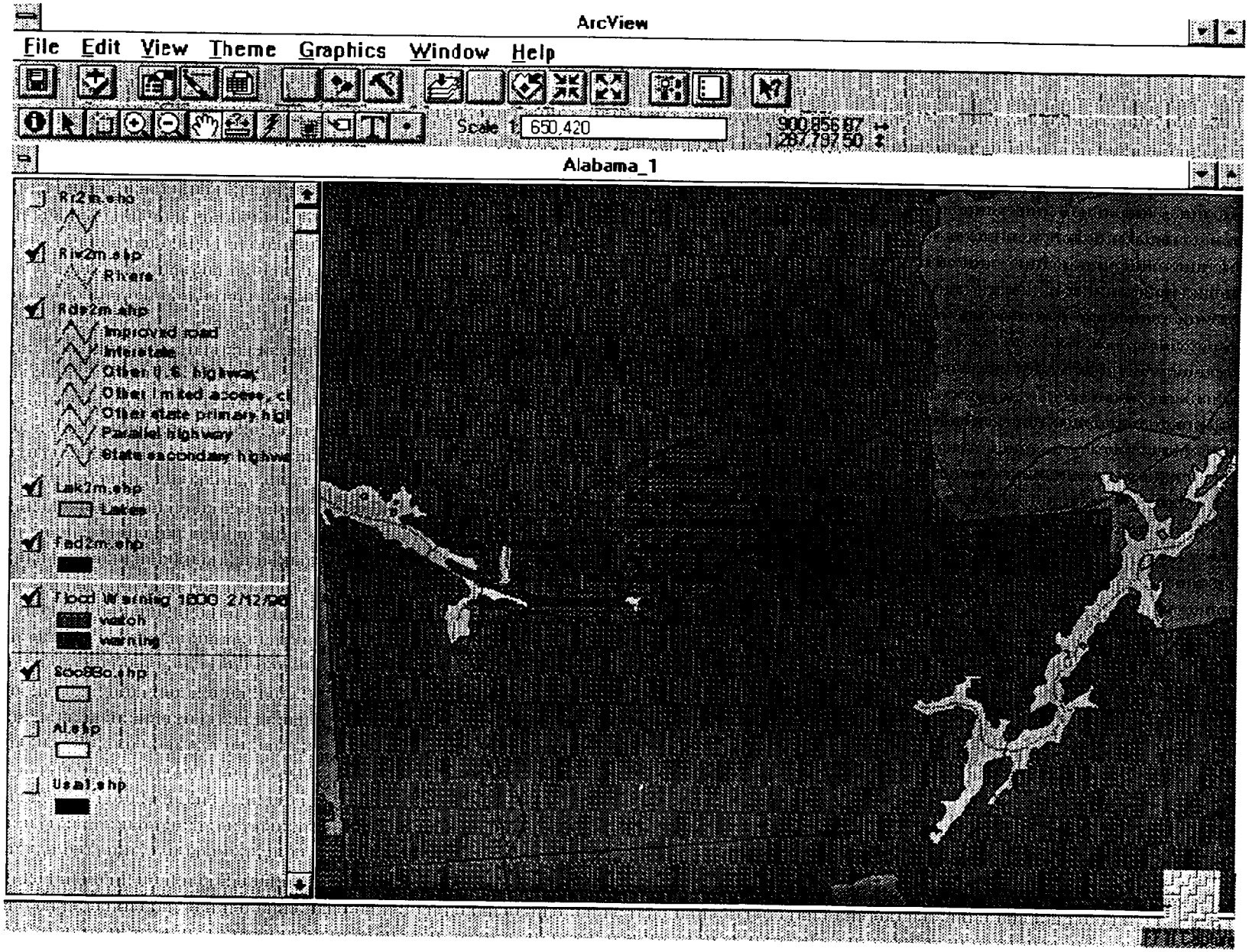


Figure 23. Sample ArcView Screen Display with Time and Date on Data Layer

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Acronym List

ADEM	Alabama Department of Environmental Management
AML	Arc Macro Language
APC	Alabama Power Commission
AVHRR	Advanced Very High Resolution Radiometer
CSEPP	Chemical Stockpile Emergency Planning Program
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
DLG	Digital Line Graphs
EDC	Eros Data Center
EMA	Emergency Management Agency
EOC	Emergency Operations Center
GIS	Geographic Information System
IP	Internet Protocol
LAN	Local Area Network
MSS	MultiSpectral Scanner
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NWS	National Weather Service
OPPS	Operational Product Processing System
TCP	Transmission Control Protocol
TIGER	Topologically Integrated Geographic Encoding and Referencing System
TVA	Tennessee Valley Authority
USGS	U.S. Geological Service
WAN	Wide Area Network
WARFS	Water Resources Forecasting System
WWW	World Wide Web